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1956-1957

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years not more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 3.00	Members	$ 8.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associate	25.00
Corporate Members	10.00	Corporate Members	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

LOCK JOINT PIPE
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NO MATTER HOW YOU FIGURE IT...

When you undertake the purchase of a new pipeline for your water supply system, do you figure from the financial angle—low first cost, economical installation and a long life for your investment?

Or are you more interested in the construction of the line—minimum excavation, easy assembly, and water-tight joints in a pipe strong enough to withstand high pressures and heavy external loads?

Then, again, your specialty may be maintenance. In that case you probably figure minimum repairs through freedom from breaks and leaks to be of paramount importance.

Or is your main concern with operation? If so, you no doubt figure permanent high carrying capacity, low pumping costs and trouble-free service to be vital.

Still, *no matter how you figure* it, your best answer will always be LOCK JOINT CONCRETE PRESSURE PIPE, because it most nearly approximates the ideal pressure pipe for water works systems.

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TWO HEADS ARE BETTER THAN FOUR!

This assembly consists of two 4-in Rockwell single register compound meters, four Fig. 143 Nordstrom valves and two 8-in reducing manifolds. The over-all laying length conforms to A.W.W.A. standards for 8-in compound meters

Dual Unit Compound Meter Manifold Is Easiest To Install and Service

An 8-in compound meter is a heavy, bulky piece of machinery. Installation is always a major problem and service a headache. You'll save time and effort—earn greater revenue by using two-meter Rockwell manifold assemblies. *They measure all the flows* with greater accuracy than a single big compound. And the complete assembly weighs approximately 100 lb less. It only takes *two* men to install.

Too, maintenance is simplified since either meter can be used to record off-peak loads while a new or repaired meter is being installed. The cost for all this accuracy and convenience is usually less than for a single big meter. Write for complete details.

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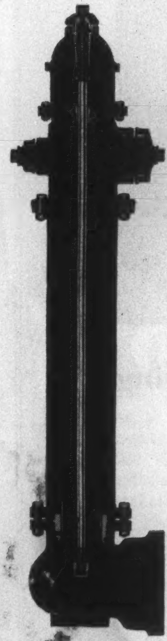
Reduce Wear, Save Time and Money with Mathews Flange Barrel Hydrant

The Mathews Flange Barrel Hydrant is designed to deliver every available gallon of water and to last indefinitely with minimum maintenance. Check these important features:



The Flange Barrel

The swivel flange at the base of the nozzle section permits nozzles to be faced toward any point in the complete circle. Saves time on original installation and on replacements.

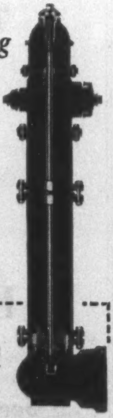
On broken hydrants, top cap and nozzle sections can usually be salvaged, thus reducing accident costs.

The Stuffing Box Plate

Cast integral with the nozzle section, the plate keeps water and sediment away from the operating thread. Hydrant remains operable in any weather. Wear on the operating thread is largely eliminated.

Breakable Flange and Stem Coupling

Optional feature furnished at extra cost. Specially designed flange in the standpipe just above ground level and a frangible coupling in the hydrant stem are designed to snap when struck a blow heavy enough to break the hydrant. Both can be replaced quickly *and without excavating*, while hydrant head, standpipe and stem remain undamaged.



ADDITIONAL ADVANTAGES

Two-way heads can be replaced with steamer and two-way heads without shutting off the water supply.

Shield operating nut protects revolving nut from sleet, snow or dust.

An extension piece may be inserted between hydrant head and barrel or between barrel and elbow.

Available with mechanical joint pipe connections.

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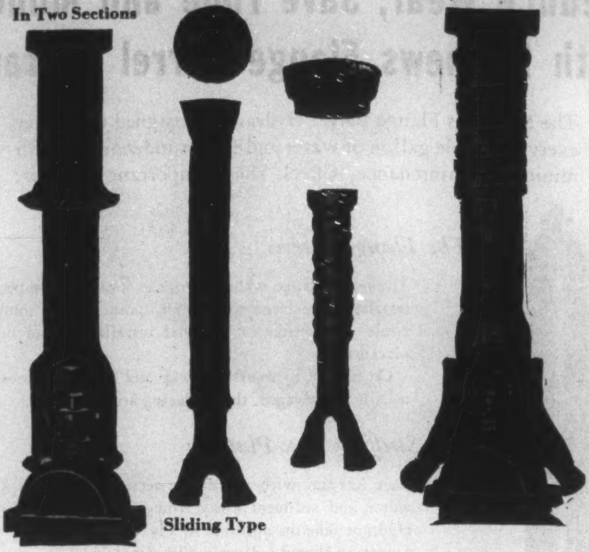
Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves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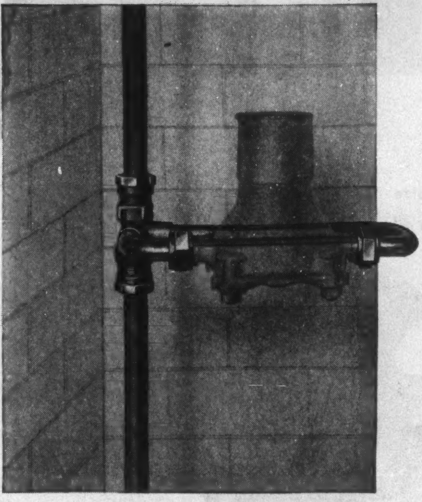
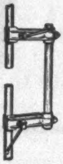


For Setting Meters in Basements

EASY TO INSTALL

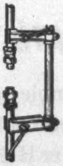
The KORNERHORN

In a vertical basement pipe, against the wall or in a corner, the Kornerhorn makes a most satisfactory meter setting. Installation is fast and economical as pipe threading is eliminated. Send for detailed information.



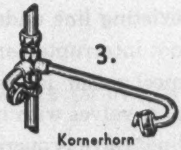
1\.

Cut supply line. Clamp not necessary but convenient



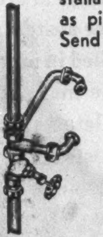
2\.

Add Connections



3\.

Kornerhorn in place



When Valves are Needed

Ford Kornerhorn valves installed on the supply side, or on both sides of the Kornerhorn add extra convenience and cleanliness when meters are changed.

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FOR BETTER WATER SERVICES

Wabash, Indiana

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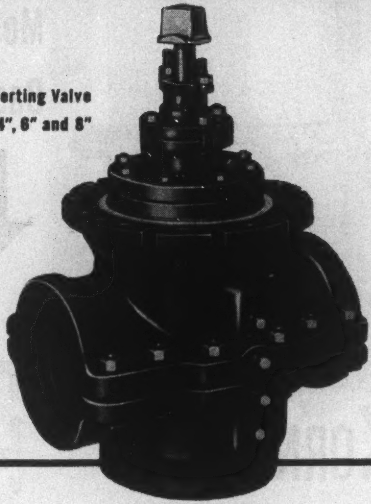
H-800 Inserting Valve
Sizes 4", 6" and 8"



ADD GATE VALVES WITHOUT SHUTDOWN

It is a simple matter to replace inoperable valves or to add needed control at vital points in your water system. The Mueller H-800 Inserting Valve may be installed in any existing line under pressure. Flow through the main is not interrupted and there is no loss of water. Gate valve mechanism is identical to Mueller A.W.W.A. standard gate valves with interchangeable parts. Once installed in line, valve is operated like an ordinary gate valve.

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Wide World Photo

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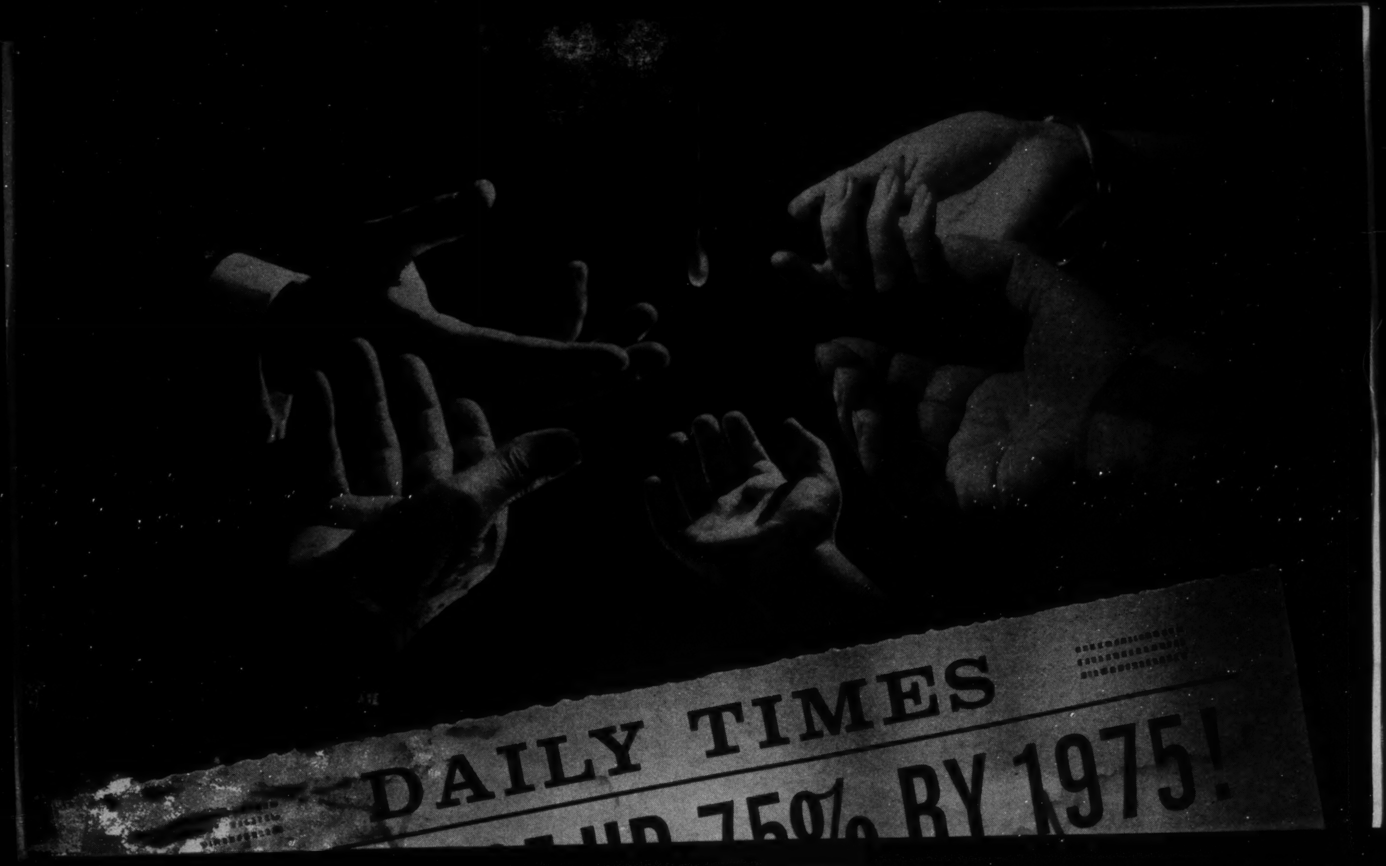
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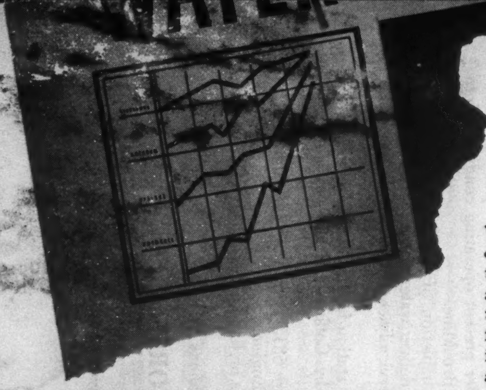

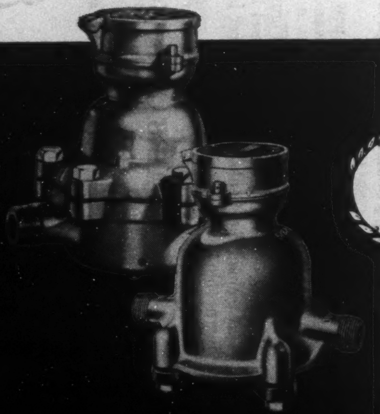

Today make sure your community can meet everyone's demands tomorrow

With the water situation already critical in many localities — and competition for water mounting alarmingly among all classes of users — conservation may well be "Operation Survival" for your community. And the first logical step is to set up an accounting of all residential and industrial water use — with Badger Meters.

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So make the first strategic move *now.* Let us send you comprehensive literature and, if you wish, set up an appointment with the Badger Meter representative in your area. He will gladly discuss your water problems and furnish complete data on the meters best suited to your community's needs.

Write us today, without obligation.

Water is Vital

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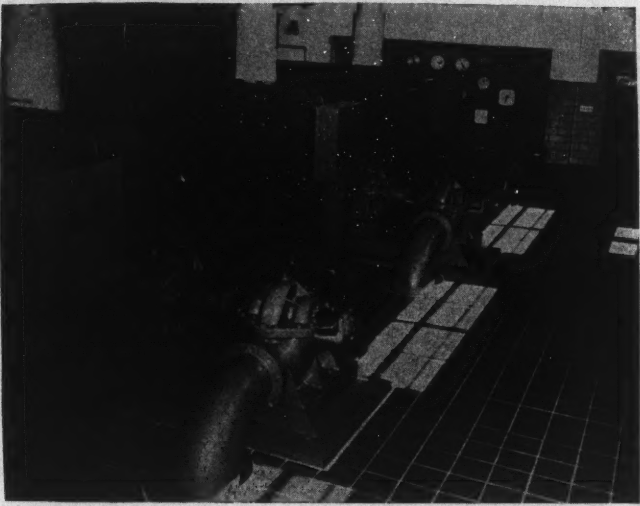

F-M Equipment at the New M.D.C. Newton Street Pumping Station, Brookline

The three Fairbanks, Morse Diesel Engine Driven Pumps pictured above are capable of delivering 4.10 Mgd under present operating conditions into the system of the M.D.C. and the town of Brookline.

Under future conditions, following completion of the Commission's proposed water system lines, the pumps will deliver water at the rate of 5.10 Mgd into the M.D.C.'s Southern Extra-High service lines and into the Bellevue Hill Reservoir.

The design and supervision of this new station for the Water Division of the Metropolitan District Commission was by Coffin & Richardson, consulting engineers of Boston.

The 10" x 12" Fairbanks, Morse Figure 5813 Pumps are each driven by a Fairbanks, Morse Model 31A6¼ Diesel Engine.

A trained Fairbanks, Morse Engineer is on hand to help solve YOUR pumping problems.

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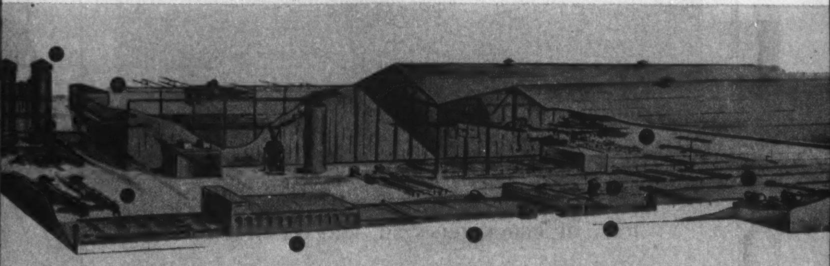

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100 years ago—WARREN was founded in Phillipsburg, New Jersey, dedicated to manufacturing a *quality cast iron pipe* for transfer of water to a growing nation. For the next 75 years pit-cast pipe in all sizes and in 12-foot laying length served as the industry standard. In fact, even in this atomic age, pit-cast pipe has no peer in larger sizes up to 84" in diameter.

Today—to meet the even greater demand of our rapidly expanding nation, WARREN manufactures in Everett, Massachusetts, *modernized* cast iron pipe, centrifugally cast in sand-lined molds. Also, currently under construction is a deLavaud pipe shop to produce cast iron pipe centrifugally-spun in metal molds in 18- and 20-foot lengths.

That 73 utilities are still using cast iron pipe installed over 100 years ago is proof of high quality and dependability of cast iron pipe.

MODERNIZED cast iron pipe, centrifugally cast, is stronger, tougher, more uniform in quality and therefore more efficient, making it the world's most dependable pipe.

Only Warren, in the United States, casts pressure pipe by the *pit-cast*, *sand-spun*, and *deLavaud* processes—thus assuring you the right pipe for your particular need.

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Shown above are two 400 HP motor driven pumping sets each consisting of two single stage pumps in series with overhead cross-over piping. The unit design conditions are 4500 G.P.M. against 300 Ft. T.D.H. The firm of Hayden, Harding and Buchanan prepared the plans and specifications and supervised the installation of all the equipment.

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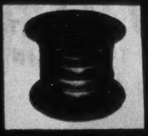

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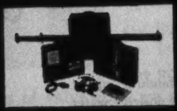

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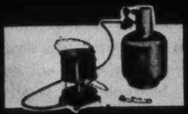

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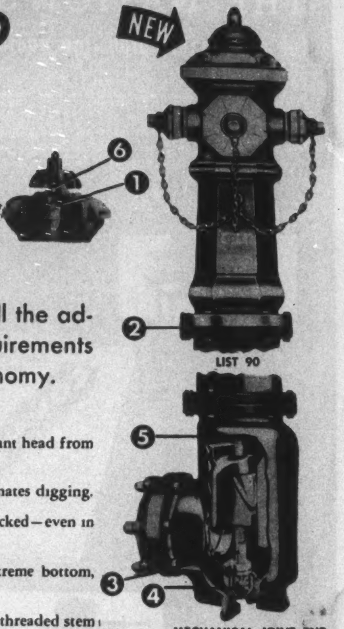

Ludlow hydrants incorporate all the advantages and meet all the requirements for safety, durability and economy.

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1. **POP-OFF SLEEVE COUPLING:** releases hydrant head from stem in event of traffic damage.
2. **BREAKABLE GROUND LINE FLANGE** eliminates digging.
3. **NO FLOODING.** Closed hydrant remains locked—even in event of traffic accident.
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5. **90,000 TENSILE STRENGTH** rolled Everdur threaded stem section completely eliminates stem failure.
6. **LESS OPERATING TORQUE.** New, non-binding upper and lower "O" rings trap lubricant . . . assure positive water tight seal . . . require no servicing.

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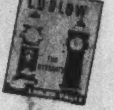

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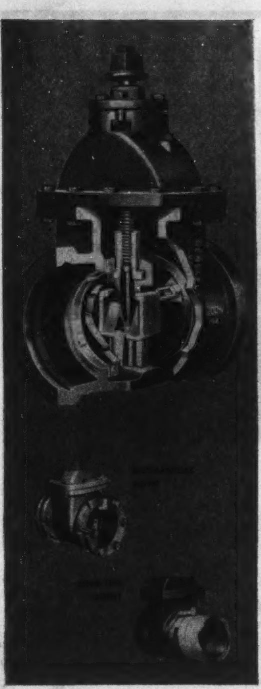
CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES



A. W. W. A.
VALVES

It costs more to dig up a valve than it does to be sure that the valve is right in the first place. Rensselaer A.W.W.A. Valves have been giving satisfactory service in hundreds of cities for many years, and there are many "reasons why."

The well known Rensselaer wedge mechanism, for instance, presses the gates firmly against the valve seats on closing, but on the first turn of the opening, the wedging mechanism is released and the gates are free.

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Only two types of valve ends are shown. All types are available together with tapping valves and other accessories.

The names, Ludlow and Rensselaer mean the same today that they have during your lifetime. The desire to serve the Water Works Field in person —in research and design and in prompt delivery of original equipment and spare parts for all products has not changed. On the other hand, our ability to serve has at least doubled.

16

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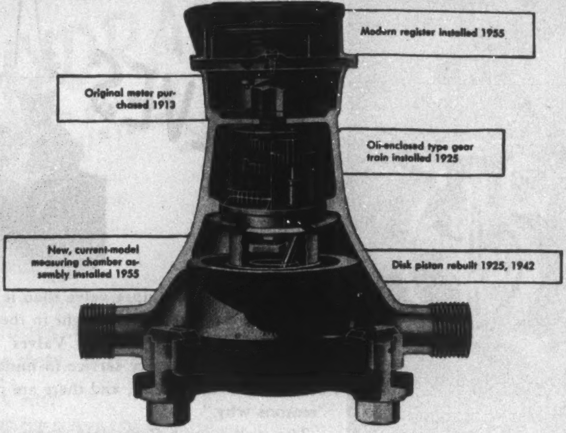

Modern register installed 1955
Original meter purchased 1913
Oil-enclosed type gear train installed 1925
New, current-model measuring chamber assembly installed 1955
Disk piston rebuilt 1925, 1942

How NEW is this Meter?

It was built in 1913 . . . but it's almost as new as 1956. Over the years, working parts have been replaced. Its performance matches every standard of modern metering practice.

The parts used to repair this meter at its last overhaul are identical to those used in the latest Trident meters. They embody every thoroughly tested advancement known to the science of metering.

Designing modern parts to fit "old" meters has been a rigid Neptune policy for over 50 years. It is just one of the extra advantages that make Tridents a better buy . . . both for today and for the years to come.

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Table of Contents

PAGE

Water-Supply Improvements and Distribution Problems at Holden
By Philip W. Hammond 235

Recent Observations of Water-Works Practices in Europe
By E. Sherman Chase 242

Integrated Equipment for Water-Works Operation Control
By Henry M. Mautner 249

The Operation of Slow Sand Filters during the 1955 Floods
By John P. Lynch 266

Experiences with Public Water-Supply Damage in the Connecticut Flood Disaster of 1955
By Warren J. Scott 275

The Case for a Positive Well-Field Maintenance Program
By E. Boyd Livesay 292

Detergent Research Related to Water and Sewage Treatment
By F. J. Coughlin 298

Elements of an Emergency Water System for Fire Service
By John C. Adams, Jr. 311

Civil Defense in Massachusetts
By John J. Maginnis 316

Water Supply, Fire Fighting and Civil Defense
By Frank P. McNea 327

Memoir of Langdon Pearse 338

Report of Committee on Rainfall and Yield of Drainage Areas—Rainfall in New England:
Part V. Rainfall in Rhode Island 340

Proceedings:
April 1956 Meeting 347
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WATER-SUPPLY IMPROVEMENTS AND DISTRIBUTION PROBLEMS AT HOLDEN

BY PHILIP W. HAMMOND*

[*Read September 19, 1955.*]

Holden is located 7 miles northwest of the city of Worcester, in central Massachusetts. Its main claims to fame are being in the path of the 1953 tornado, and having the first regional high school built in Massachusetts and the first town-manager form of government in Worcester County.

Previous to 1955 the water supply was obtained from Muschopauge Pond, located in the town of Rutland, about 0.3 mile from the Holden town line. Holden's right to use this supply was established by Chapter 180, Massachusetts Special Acts of 1896, and limited only by the prior rights of Rutland, which have not been defined by legislation. Service was supplied by gravity from Muschopauge Pond through a 20-in. intake and 14-in. to 12-in. to 10-in. mains, laid in 1905. The pressure gradient of the system is determined by the water level in Muschopauge Pond at elevation 1,028 ft above mean sea level, creating a water pressure of 60 lb to 140 lb.

Muschopauge Pond has a drainage area of 0.51 square mile, a water surface of 63.5 acres (19.5% of the total drainage area), and a storage of 225 mil gal for the top 12-foot depth. The safe yield of this supply is estimated at 450,000 gal per day. The present average daily consumption of the towns of Holden and Rutland is 680,000 gal per day.

In 1930 the lowest water level of record was measured at 12.5 ft below high water, at which time Holden lowered its intake, by installing a 12-in. cast-iron-pipe inverted siphon, to a point 32 ft below high water and installed a vacuum pump to keep the siphon primed, so as to permit water to be drawn at a level of 22 ft below high water.

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Population growth in Holden had been fairly constant, from 2,000 in 1905 to 3,500 in 1930; with a leveling-of during the depression and war years it reached 6,000 in 1950. By 1955 we were at 9,000-plus population. Like other communities, our water consumption had increased from an average of 182,000 gal per day in 1935 to 413,000 gal per day in 1955, with a peak day of 926,000 gal in August. In 1935 Holden's water system consisted of 674 takers; in 1950, 1,465 takers; and in August, 1955, 2,060 takers of water. At the end of 1954, Holden had 45 miles of water mains and 289 hydrants. The system expanded 12½ miles in the last 4 years.

During the summer of 1949, the draft on our system was great enough so that families in the highest section of town were without water for about 3 or 4 hours on high-consumption days. This fact was immediately reported to the Board of Water Commissioners, and they in turn asked the town at a special town meeting in November to appropriate the sum of $3,000.00 for an engineering survey, which was granted.

The firm of Metcalf & Eddy was employed to make such a study and report to the Commissioners as soon as possible. The engineers reported in 1950 that the town should:

#1. Explore Quinapoxet Valley and other suitable locations for development of an auxiliary ground-water supply or negotiate with the city of Worcester for purchase of water.

#2. Construct a meter and chemical building near the present reservoir.

#3. Lay 12-in. pipe in Millbrook St. and North Main St.

#4. Erect a 500,000-gal elevated storage tank in Chaffins section of town (the section of town where we had our first pressure problems).

#5. Erect a 500,000-gal elevated storage tank in Holden Center, along with some necessary increase in size of main.

Articles were put in the 1951 annual town meeting for the construction of the elevated tank in Chaffins, the construction of a meter and chemical building, and for water exploration. Of these three, the articles for the construction of the meter and chemical building and the water exploration were approved.

During this period the two miles of 12-in. Transite pipe, suggested by the engineers, was laid by the Water Department from near the reservoir to the village of Jefferson. This pipe gave added flow for fire protection and a dual line to this point in case of a break in the old 14-in. cast-iron pipe.

Negotiations were started in 1951 with the city of Worcester for the purchase of water from their reservoirs, which are located in Holden. The last large body of water in Holden had recently been purchased by Worcester from the Metropolitan District Commission, this water being transmitted through a 36-in. pipeline to the Worcester system, which at one point crosses our 12-in. supply line. It was at this crossing that we had hoped to procure a supply from Worcester, but Worcester, having the same problems of water shortage, did not care to sell water to Holden. However, Worcester did agree that if Holden could not find a suitable ground-water supply, they would be willing to negotiate further after completion of their new Quinapoxet Reservoir.

Negotiations were also started in 1951 with the Metropolitan District Commission in Boston for the purchase of water from their Quabbin Tunnel, which passes under Holden, Shaft 4 being about 1 mile from our supply line. It was suggested by the Metropolitan District Commission that, due to the poor quality of the water in the tunnel during certain periods of the year, it would be better for Holden to procure a ground-water supply. Some of the water passing through the Quabbin Tunnel comes from the Ware River and has not had a chance to settle until it reaches Wachusett Reservoir in Clinton.

During this period from 1951 to 1954 inclusive, a restriction on watering lawns was asked for by the Commissioners with very good results, there being relatively few who did not care to cooperate.

In accordance with the engineers' recommendation, the town of Holden appropriated money to seek an additional supply of 1 mgd. It was hoped that this supply could be obtained from one well, or two at the most. The results of extensive test-well work during the years 1951 through 1953 proved that the finding of a million-gallon well or obtaining 1 mgd from any one location or area was seemingly impossible.

In 1953 the town adopted a selectmen-town manager form of government, with the duties of the Water Commissioners taken over by the Selectmen. At this time it was decided to change engineering consultants to Whitman & Howard of Boston, and L. M. Pittendreigh was assigned to study Holden's problems.

The engineers' report was substantially the same as previously reported by Metcalf & Eddy with two exceptions: (1) the 500,000-gal elevated tank proposed in Holden Center was changed to a 1,000,000-gal standpipe and (2) the 500,000-gal elevated tank in Chaffins section was changed to a 250,000-gal elevated tank.

Experience proved that Muschopauge Pond supply was limited. Therefore Whitman & Howard also stated in their report that the town should further test each location where some water-bearing material was found. As a result of this, additional money was appropriated for this purpose.

In 1953, 27 wells were driven, totaling nearly 1,000 ft in depth, or an average of 37 ft in depth per well. In nearly every case the well terminated on ledge. Therefore, in general, the overburden was found to be shallow. However, two favorable locations were found—namely, near the corner of Manning and Wachusett Streets (which we are testing by means of a pumping test at the present time), and the Packard's pit area off Spring St., in the Asnebumskit Brook valley. In the latter area test wells revealed approximately 41 ft of reasonably good water-bearing sand and gravel. An 8-in. test well was driven, together with observation wells, the 8-in. well being 41 ft deep and including a 10-ft screen at the bottom. A deep-well pump was installed and the well pumped for 6 days at 122 gal per minute.

Records of the water levels were kept and plotted. The important point in the plot was that in the observation well, 2 ft away from the 8-in. well, the water level was lowered about 8 ft and reached a stabilized level on the 5th day, with a yield of approximately 15 gal per foot of drawdown, or at least 200 gpm in a large gravel-packed well.

The quality of the water at Packard's Pit off Spring St. is excellent. The water is low in iron and contains no manganese, being practically the same as the water in Muschopauge Pond in every respect.

As a result of this test work, a supplementary report from the engineers recommended the construction of a gravel-walled well, and at the annual town meeting in 1954 the town voted to do so. A contract was awarded to R. E. Chapman of West Boylston to build the well. The excavations for the well were made by steel caissons, varying in size from 60 in. to 48 in.

The water is pumped by means of an electric motor-driven turbine pump, housed in a brick building. Treatment consists of the addition of soda ash and Calgon, as is carried out on the Muschopauge supply.

At the annual town meeting in March, 1954, the town voted to construct a 1,000,000-gal standpipe in Holden Center and a 250,000-gal elevated tank in the Chaffins section, along with the necessary pipelines.

The elevation of the overflow of any water-storage facilities in a gravity supply system presents somewhat of a problem. If the overflow of storage facilities were constructed at the same elevation as the reservoir, the full volume of the facilities would not be used, as they would never be full. This is due to the fact that in a gravity system there is water flowing in the supply mains 24 hours a day. Therefore the hydraulic grade line at Holden Center or in Chaffins would always be below the elevation of the reservoir.

If the overflow of the storage facilities were too low, the water would remain stagnant, except in case of fire or exceptionally heavy consumption. Likewise, the elevation of the overflow could be designed for average conditions, so that the stored water would change constantly, as the consumption varied. With an elevation at the reservoir of 1,028 ft above sea level, it was decided that the hydraulic grade line would be at elevation 1,010 ft above sea level at the Holden Center Standpipe and at 1,000 ft above sea level at the Chaffins Elevated Tank. The overflow of the standpipe is 52 ft above the concrete base, and the overflow of the elevated tank 157 ft above the concrete base.

Susi & Desantis of Boston were awarded a contract to lay 5,000 ft of 12-in., 1,000 ft of 10-in., and 1,800 ft of 8-in. Transite pipe and to construct foundations for both tanks, construction getting under way in June, 1954. Chicago Bridge & Iron Co. was awarded a contract to erect both tanks. They were completed in January, 1955, and filled and used at that time without painting, due to cold weather.

In February, the engineers recommended that cleaning of the old 12-in., 10-in. and 8-in. supply be undertaken before hot weather. The cleaning was delayed by the question as to whether the work was to be done by contract or by the Holden Water Department.

In May the elevated tank was drained and the painters proceeded to complete the tank. Before this was finished a very hot spell hit us, with a resultant high consumption of water, and difficulty was experienced in maintaining water in the elevated tank, due to the low coefficient of friction in the old 10- and 8-inch pipe feeding the Chaffins area, which up to that time had not been cleaned. The high consumption was due to the unrestricted uses of water plus the fact that the 1-mil gal standpipe maintained a higher hydraulic grade line in the system than had ever been experienced prior to the construction of the storage facilities.

In 1955 our consumption increased from an average of 368,000 gal per day to an average of 413,000 per day, and during the hot, dry days it reached a high of 926,000 gal per day. For this reason it was decided not to paint the standpipe until fall.

It was at this time that the Selectmen, who were now acting as Commissioners, decided that the Water Department employees should do all work necessary to cleaning the 12-in., 10-in. and 8-in. supply mains, some of which were laid in 1905 and some in 1925. Flex-o hydraulic pipeline scrapers were used, and the results were satisfactory.

The engineers suggested that the old, existing 10-in. and 8-in. supply mains, which we were going to continue to use, should be cleaned first. There is a total of 2.5 miles of 10-in. pipe and 0.6 of a mile of 8-in. pipe. The cleaning of these lines was divided so as to complete the actual cleaning in 3 days. The first day, 1.8 miles were cleaned in 14 hours of shutdown time (the excavations were all done previously); the second day, the balance of 0.7 of a mile of 10-in. pipe was cleaned, and the third day, the 0.6 of a mile of 8-in. pipe was cleaned. The only difficulty incurred during all of our cleaning was on the second day, when we temporarily lost our cleaning tool in a 10-in. tee, of which we did not have a record.

With the installation of the storage facilities water-service interruptions were kept to a minimum. While the 10- and 8-inch mains were being cleaned, the Chaffins area was supplied from the elevated tank.

As soon as the excavations for the 10-in. and 8-in. pipe cleaning could be backfilled, new excavations were made to clean the 12-in. pipe. The 1.4 miles of 12-in. pipe were cleaned in two sections without serious trouble in two days. During the cleaning of the old, single, 12-in. supply main, laid in 1905, Holden Center and Chaffins area were supplied from the standpipe and elevated tank.

The coefficient of the old iron pipe was found to be 45 before cleaning and 125 after cleaning. Calgon was applied at the rate of 4 ppm after cleaning and will be continued indefinitely at 2 ppm to control the further growth in these mains.

At the end of each section to be cleaned a short section was removed, to permit the attachment by means of a Dresser coupling of a ⅛ bend with two short nipples, made up in advance. A Dresser coupling was also used to connect another pipe, to bring all water and rust to the surface. By making this in two sections, we could use our own small backhoe to lower the larger pipe into place.

To follow the progress of the cleaning tool, we found that the use of a Sonoscope on the service boxes and a Geophone Leak Locator served the purpose. As we had previously shut off all services and side-street mains, their locations were known.

After the cleaning of the mains the distribution system with the new storage facilities supplied unrestricted water to the consumers with a maximum drop in pressure of only 10 lb at any time. This was true during the week ending August 8, 1955, when consumption averaged 759,000 gal per day and even during the maximum two-day period with over 900,000 gal per day. Previous to 1955 the maximum day's consumption was 650,000 gal, at which time the Chaffins section was without water.

At the present time additional test-well work is being undertaken, and if we are unsuccessful in finding the required additional ground-water supply, with all potential surface supplies acquired by others, the town of Holden will have to petition the Legislature to ascertain its rights in Muschopauge Pond and require the Metropolitan District Commission to furnish sufficient water to meet the town's needs.

RECENT OBSERVATIONS OF WATER-WORKS PRACTICES IN EUROPE*

BY E. SHERMAN CHASE†

[Presented Sept. 20, 1955.]

I had two reasons for my European trip this last summer. The first reason was to attend the summer meeting of the Institution of Water Engineers, upon which I reported at yesterday morning's session, as you who were present at the opening session will remember. The second reason was attendance at the Third International Water Supply Congress in London, at which I was a "general rapporteur" on one of the nine subjects under discussion.

The summer meeting of the Institution of Water Engineers was held at Richmond outside of London, upstream on the Thames. The course of the meeting was about as it usually is, with only one or two prepared papers and a number of excursions to water-works undertakings in the vicinity, particularly to works of the London Metropolitan Water Board, none of which was too far away, and also to a new water undertaking in the County of Surrey, also not far distant. The meeting, as usual, was characterized by quite a number of social functions. I think the Institution puts a little more stress on social activities and excursions to works, perhaps, than we do, and not quite so much on technical matters.

The Third International Water Supply Congress was attended by delegates from something like 37 different countries, ranging from Australia and Indo-China to Mexico and the United States. Here the procedure was quite different from anything we have over here. There were some nine different subjects under discussion. The way these discussions functioned was by the appointment a couple of years ago of a general rapporteur for each of the subjects, who had associated with him national rapporteurs from many different countries. In my case there were something like 17 different countries represented by national rapporteurs. The national rapporteurs sent to the general rapporteur answers to questionnaires, data and general information on the subject that the general rapporteur had to report upon.

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*Talk with lantern slides at the Lake Placid convention.

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At the session the general rapporteur would give a summary of his report which, incidentally, had been printed in advance and had been distributed in pamphlet form to all of the attending delegates. Consequently, most of the delegates had had a chance to read the report and digest the findings and conclusions, and, if a delegate so desired, he could come prepared to discuss the report. The report, being given in summary form, did not take many minutes. I think I took about 20 minutes, and then the discussion lasted the rest of the afternoon. Sometimes a matter was discussed without any evidence of a controversy, such as we see in the case of the discussion of fluorides; in other cases we got into quite a discussion, particularly in my own case, the subject of which was methods for charging for water, the controversy being whether to meter or not.

To a very large extent the English as a whole look with abhorrence upon meters. On the continent, on the other hand, there seems to be an increasing desire to install meters. Perhaps the reason for the reluctance of the English to resort to metering as a basis for charging for the water which is used by the individual consumer is the fact that the English seem to have a rather socialistic point of view. Their point of view is that every citizen is entitled to an ample supply of good safe water and that he should pay for it, not in accordance with how much he uses, but in accordance with his ability to pay. This philosophy results in charges upon the assessed value of the property served. In other words, it is just another form of taxation, like a real estate tax, which is quite contrary to our general thinking over here.

Most water-works men over here think of their service as a business proposition and that people should pay for what they get, which is not in conformity with the British point of view: namely, that everybody should have water almost as freely as air.

Of English water works in general I did not have an opportunity to see very many on this trip. I did see quite a little of some of the London Metropolitan Water Works, which I had seen before. But on occasion of the Institution meeting excursions took us to the older

Hampton Works, which are the largest works operated by the Board, with a filter capacity of about 120 mgd, and a capacity for providing about 45 mgd additional, either partly treated or without treatment.

Many of our members probably remember Mr. Cronin's talk at Groton in 1952, when he described the London Water Works,* but probably not the details. Roughly two-thirds of the supply of London comes from the Thames. This water is pretty badly polluted in the raw state, so that before filtration it is stored in large open reservoirs. These reservoirs are constructed in a substantially flat plain by digging a big hole in the ground and forming a circumferential embankment all around the hole, so that it is like an enormous washbowl. The Hampton Works supply comes from the Queen Mary Reservoir, 130 acres in area, built 25 or 30 years ago. As the result of the poor quality of raw water, the large amount of food material provides for heavy growths of algae, aggravated by the long period of storage.

Incidentally, the Thames River water is very difficult to coagulate with ordinary coagulating chemicals. The water is so difficult to handle that the idea of coagulation for rapid sand filtration has been given up. The result is that, although the original Thames supply was filtered with the old slow sand filters, clogging of the filters became so serious that they have installed, ahead of the slow sand filters, both older ones and new ones, rapid sand filters, which are used without the coagulant. Without coagulation the rapid filters simply act as strainers.

At the Hampton Works they have 32 rapid sand filters used without coagulants, covering an area of about 1 acre, followed by what are called secondary filters, which are slow sand filters, something like 38 units, covering nearly 42 acres.

Following filtration, chlorine is used for disinfection, and at the Hampton Works there are both high and low pumping services.

The other major works which we visited were the Ashford Common Works, which is the first major construction job undertaken by the Water Board since the war. Mr. Cronin spoke about it when he was here 3 years ago. This plant was under construction 6 years ago and is still not completed. They have had a good deal of difficulty in getting materials, equipment, etc. Particularly during the previous national administration the water works were sort of a stepchild, as far as the administration was concerned, and other things, such as rural electrification and housing, etc., got priority. It seems to me that, not unlike it is over here, the last thing that is thought about or given attention is the water-works industry. We have to stand up and holler to get attention. Other things, which to us, at least, seem less important, get priority.

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*Cronin, H. F. This Journal 67:3, 153, Sept., 1953.

The Ashford Common Works will have a capacity of 90 mgd. These are English gallons, and it takes 5 U. S. gallons to make 4 English gallons. This plant will include 24 microstrainers, which were described to us last March by Dr. Boucher.* These will be 10 ft long and 10 ft in diameter—very large pieces of equipment—followed by 32 slow sand filters, covering an area of 24 acres. These filters are expected to be able to handle the water after passing the microstrainers. Slow sand filters at other plants have handled the water that has passed through rapid sand filters. Before the microstrainers were adopted instead of rapid sand filters, experiments were carried on for 2, 3 or 4 years with a 5-mgd pilot plant with microstrainers. After microstraining the water was run through existing slow sand-filter beds, to demonstrate beyond doubt that the sand filters could be operated preceded by microstrainers, instead of the more expensive, rapid sand filters. After sand filtration the water will be given a final chlorination, followed by a 2-hr contact period.

At the Ashford Common Works there will be two types of cleaning mechanisms for the slow sand-filter beds, one of which will involve skimming off the dirty sand and removing it for washing outside the filter. The other is a new development of a mechanism which will wash the sand on the bed without removing it.

Another trip was to the offices of the Metropolitan Water Board, which are located on the site of the original water works of London from the so-called New River Supply, brought into London in 1613 by Sir Hugh Myddelton, the engineer. At this location are not only the head offices of the Board but also a large laboratory for the maintenance of the quality of water, research work, and similar activities.

It is of interest to this Association that in the foyer entrance to the laboratory there is a plaque showing the head of Sir Alexander Houston, who was an honorary member of this Association at the time of his death, about twenty years ago. He was the first director of water examination for the Metropolitan Water Board and was responsible for the pioneering work in the disinfection of water by the use of chlorine.

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*Boucher, P. L. This JOURNAL 70:1, 1, March, 1956.

Another trip was out to a new development, the so-called Weir Wood Water Board Supply, in the County of Surrey, not so far from Richmond, where there had been completed recently an earth dam forming an impounding reservoir of some 1,240-mil gal capacity, with about a 10-sq mi drainage area, and with a net yield of about 3 mgd, at a cost of about $4,200,000.

The English, I think, go in quite a lot for earth dams, using clay core walls and bell-mouth spillways.

The water after impounding is delivered under gravity to a filter plant, where it is prechlorinated, coagulated, passed through a sedimentation basin, through the sand filters, and finally chlorinated. Lime control of the pH index is also provided. The filtered water is delivered through a couple of trunk mains to the district to be served, one main being a 24-inch and the other a 12-inch, each lined and sheathed with bitumen and provided with cathodic protection.

I do want to mention the fact that a very interesting development has taken place since the war in The Netherlands, under the auspices of the Institution of Water Engineers of The Netherlands and The Netherlands Water Works Association. As in Great Britain, there are two Associations; the Water Works Associations are comparable to our New England and to our American Water Works Associations, which are made up of water-works men of all types: water superintendents, manufacturers' representatives and water boards, as well as engineers, chemists and other technical men. In contrast, the Institutions of Water Engineers in both The Netherlands and Great Britain are made up of simply engineers and technical personnel. Consequently the two associations are quite distinct, although they have many members in common.

In 1948 the two Netherlands associations founded what is called the Institution of The Netherlands Water Works Undertakings—KIWA, Ltd. The purpose of this organization is to collaborate with the central government and organized water-works undertakings, to test materials, carry on research, maintain laboratories for water examination, and promote any activities of interest to water-works people. It is incorporated, and there are something like 400 shares at a nominal value of $25 each. The proprietors of the water works own shares, from 1 to 8 shares each, and each of the two founder organizations has 40 shares. KIWA carries on research in connection with water-supply activities, tests materials, makes bacterial and chemical examinations of water supplies, and stamps its approval on materials which have been tested and found satisfactory. That KIWA approval is something like the Good Housekeeping approval on household utensils and materials. At the Congress KIWA had an extremely interesting bulletin for distribution, which described in considerable detail just what it does.

Some of the general impressions I brought back with me may be of interest. The first is that most of the water works in Europe, and certainly in England, are municipally owned. Relatively few water supplies are privately owned. Apparently the political philosophy is rather against private ownership of water works. Another thing which is quite different from over here is that when water is diverted from a watershed and storage reservoirs are built to impound the water, the diverters are required, particularly in England, to provide compensation water to the lower riparian owners. In the case of Sheffield at least 43% of the yield of the watershed has to be let down to the lower riparian owners. Over here, as you know, we usually have diversion suits and the matter is settled by the payment of monetary damages.

I referred to the aversion to metering in England, and we at the Congress had a lot of discussion of that. There was one man in favor of metering, for years "a voice crying in the wilderness," who was very happy to get some support in the Congress, because many of the European water engineers also were in favor of metering.

Another thing that you will notice over across is the almost complete absence of hydrants, that is to say, above the ground. Connections for fire hose are underneath the pavement. Over the connection there is a little plate which can be lifted and under which is a turn-on valve. How they ever find those places after dark I do not know.

Then another matter of interest is that English water mains, at least, are much smaller than ours. Perhaps there is less need for larger mains, inasmuch as the houses and buildings are of fire-resistant construction, of brick and stone. They do not have the fire problems that we do and they do not need, apparently, large volumes of water for fire fighting. In the rural districts of England, where I spent perhaps a week or 10 days driving around, miles and miles of small pipe are being laid of 5- or 6-inch diameter. They have 5-in. pipe, 7-in. pipe and 9-in. pipe, which sounds a little strange to us. But there were miles and miles of this small-diameter pipe going through the countryside, with the houses perhaps a half-mile apart. No water works over here would ordinarily attempt to extend the water mains into such a rural territory. I understand that the Central Government is subsidizing what they call the water grid to the rural areas.

Another thing which they do over there more than we do, because of the small size of the mains, is to clean and line in place. This is particularly true in the cities up in the Midlands; for example, Manchester and Sheffield, where the water supplies are very soft and very corrosive.

In general, I should say that the problems which are encountered over there are not dissimilar from ours, with some modifications. You can get some idea of it by the topics which were discussed at the Third International Water Supply Congress. I shall just name them: (1) comparison of the slow sand and rapid sand filters; (2) training water-works operators; (3) factors of safety in supply and delivery systems; (4) pumping-station equipment; (5) aeration and deferrization; (6) protection of pipelines against water hammer; (7) use of electronic apparatus in water-works practice; (8) design and construction of service reservoirs and water towers; and (9) my own topic, methods of charging for water.

All those topics were things we have discussed and worried about ever since the New England Water Works Association has been in existence. Certainly one of the earliest reports on what to charge for water was made by a committee of this Association about 60 years ago. I think it was the first one in this country.

So, take it by and large, the headaches of water-works men are the same the world over.

INTEGRATED EQUIPMENT FOR WATER-WORKS OPERATION CONTROL

BY HENRY M. MAUTNER*

[*Read Sept. 21, 1955.*]

The functional operations of a water-works system are: (1) to provide supply from some source (ground or surface), (2) to treat the water when necessary, and (3) to distribute the water to the users. In each of these functional operations, there is need for control, which can be obtained by equipment integrated into the several individual operations that make up the overall operation of a water-works system.

What Is Control?

In discussing the importance of various controls, perhaps the first question to answer is, "What is control?". In an article on "Instrumentation and Control" in the May, 1955, issue of *Water & Sewage Works,* Dr. George E. Symons defined the subject as follows: "Control is the term applied to the selection, installation, application and use or operation of devices which regulate the functioning of other devices or which regulate physical actions or conditions or chemical reactions." In that article, Dr. Symons also defined the elements of a control system and the six degrees of control obtainable.

The elements of a control system include a sensing device, transmission system, instrument with control device, sentinel alarm, feed-back, and control panel. The six degrees of control possible are: Manual, semi-automatic (including step control), program (sometimes termed time-cycle), proportional pacing, combinations of these, and fully automatic (feed-back). It is not the purpose of this present paper to discuss the definitions and details of these elements of a control system and degrees of control obtainable. Reference should be made to the original article mentioned for that information. This paper will deal with some of the equipment integrated into control operations.

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What Controls Are Important?

The importance of individual controls or control systems depends on the problem in the basic operation involved. Certain fundamental operations in the collection or obtaining of a water supply need to be controlled, but that same operation may not exist or may need no control in the treatment or distribution phases of a water system. In short, each functional operation in a water-works system will generally be concerned with controls specifically related to that operation.

COLLECTION OR SOURCE OF SUPPLY

Water supplies may be obtained from surface sources, usually impounded reservoirs, or from ground-water aquifers. In either case two things may be important to the operator: level of, and flow rate from, the supply source.

Level

In impounded reservoirs, it may not be control of the level that is possible—nature may do that—but it may be the record of the status of the level that is desired and important to the operator. In a well field, it may be the draw-down level or the static level that is controlled or sought.

In either case the element which actually senses the existing condition may be a float, pressure bellows or Bourdon tube, bulb diaphragm, or bubble pipe.

Flow

Regardless of the source of supply (surface or ground), one thing the operator wants to know (and in many cases to control) is the rate of flow.

The most common devices used to sense or determine rate of flow are differential head producers and velocity-type or propellor meters, although pitot tubes are used in some instances and head-area measuring devices are sometimes used on flumes or open conduits. Among the differential head producers are the Venturi tube (long and short form), the nozzle, the Dall flow tube, and the orifice. Head-area devices include weirs and the Parshall flume. The Gentile flow tube is, in effect, a multiple pitot-tube arrangement with the ports at the surface of the tube, rather than at the center of the tube as in the regular pitot-tube arrangement.

Transmission

Quite generally, the source of supply is located at some distance from the treatment works or distribution system. Under such circumstances, it is necessary to transmit the information over appreciable distances. If the distance is only a relatively few feet, the information may be transmitted from the sensing element to the instrument or control unit by direct connection, such as a cable, or static pressure connections (Fig. 1).

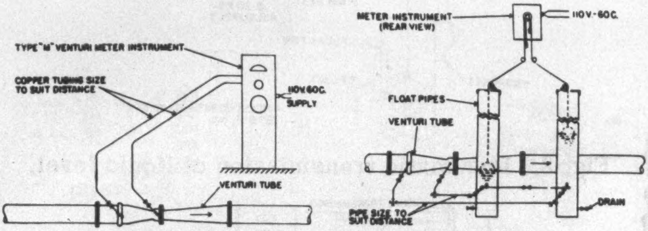

TYPE "M" VENTURI METER INSTRUMENT
COPPER TUBING SIZE TO SUIT DISTANCE
110V.60C. SUPPLY
VENTURI TUBE
METER INSTRUMENT (REAR VIEW)
110V-60C.
FLOAT PIPES
VENTURI TUBE
PIPE SIZE TO SUIT DISTANCE
DRAIN

Fig. 1. Direct transmission of flow measurement.
(Left: Pressure) (Right: Float & Cable)

If the distance from sensing device to control station is under 1,500 ft, transmission may be by air pressure. This pneumatic system utilizes an output air pressure which varies between 3 and 15 psi, with the lower pressure representing zero and the higher pressure 100% of the variable being sought (Fig. 2). Pneumatic systems have the advantage of immediate response, incremental variation, and single connection, free from outside influences.

Where the distance from sensing device to control station is more than 1,500 ft and up to 100 miles or more, transmission of the information sought is by electrical current (Fig. 3). This system is generally known as telemetering. Telemetering is used particularly for simple transmission of information on level, flow, pressure, temperature, etc. Builders Chronoflo Telemeter system has also been used for control, as will be described later.

The Chronoflo Telemeter consists of two parts, a transmitter and a receiver, connected by a simple two-wire circuit (Fig. 4). The basic elements of this telemetering system are a magnetically-operated mercury switch in the transmitter, a relay, and a set of up-and-down clutch coils in the receiver. Rates of flow, liquid level, positions, pressures or temperatures are translated into cyclic time impulses, the duration of which has a definite relation to the quantity being measured. These cyclic time impulses are transmitted to the receiver and translated into indicated, recorded or totalized information.

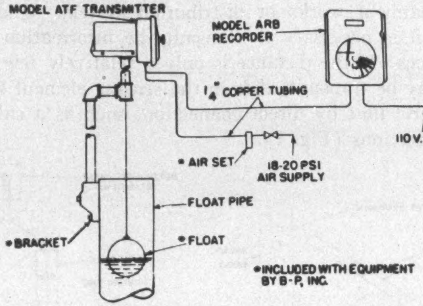

MODEL ATF TRANSMITTER
MODEL ARB RECORDER
1/4" COPPER TUBING
110 V. 60 C.
* AIR SET
18-20 PSI AIR SUPPLY
FLOAT PIPE
* BRACKET
* FLOAT
* INCLUDED WITH EQUIPMENT BY B-P, INC.

Fig. 2. Pneumatic transmission of liquid level.

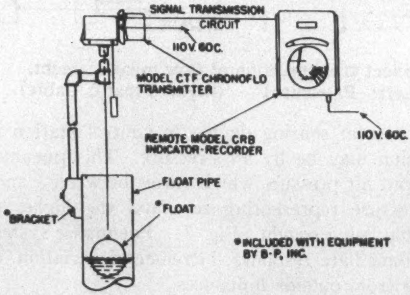

SIGNAL TRANSMISSION CIRCUIT
110 V. 60 C.
MODEL CTF CHRONOFLO TRANSMITTER
REMOTE MODEL CRB INDICATOR-RECORDER
110 V. 60 C.
FLOAT PIPE
* FLOAT
* BRACKET
* INCLUDED WITH EQUIPMENT BY B-P, INC.

Fig. 3. Electric Telemeter transmission of liquid level.

Supervisory Control

Another form of remote control is termed "Supervisory Control", one commercial type of which is known as Synchro-Scan. By utilizing this system, a single pair of signal wires with the Synchro-Scan components can accomplish two-way transmission of multiple telemetering and advisory functions (Fig. 5).

This supervisory control system usually consists of a central dispatching panel and associated terminal receiving equipment at the remote, unattended stations (Fig. 6). In this panel are the dispatching scanning-switch assembly, control units with indicating lamps and switches, and the metering instruments. The terminal receiving equipment consists of the receiving scanning-switch assembly and control relays, linking the Synchro-Scan impulses with the controlled devices or instruments.

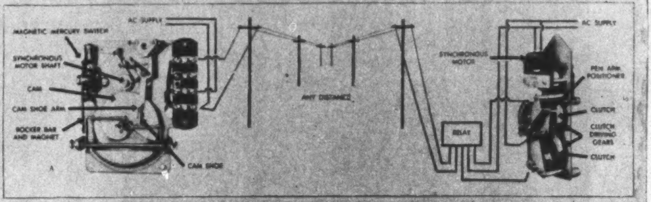
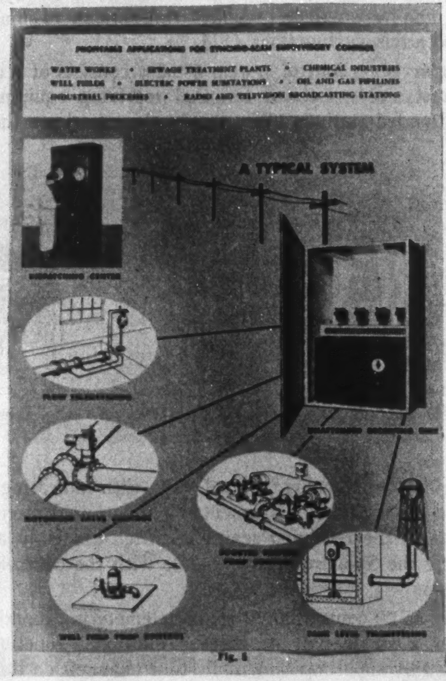

MAGNETIC MERCURY SWITCH
SYNCHRONOUS MOTOR SHAFT
CAM
CAM SHOE ARM
ROCKER BAR AND MAGNET
A
AC SUPPLY
CAM SHOE
ANY DISTANCE
SYNCHRONOUS MOTOR
RELAY
AC SUPPLY
PEN ARM POSITIONER
CLUTCH
CLUTCH DRIVING GEARS
CLUTCH

Fig. 4. Chronoflo Telemeter transmitter and receiver arrangement.

As many as 29 control, advisory or telemetering functions can be handled over a single pair of wires. Additional functions can be accommodated by superimposing audio-tone channels on the basic system. "Plug-in" components are used throughout the equipment, each control device being connected to an individual plug-in chassis (Fig. 7). These plug-in scanning switches are self-synchronizing and, with accompanying relay and rectifier equipment, energize or de-energize the relays associated with the control or advisory equipment. Time-impulse telemetering can be incorporated into the system.

Controls Effected

In most instances, levels in reservoirs are not controlled directly, except by control of the discharge. Rate of flow by gravity from a reservoir can be controlled by positioning a gate or butterfly valve in the outlet or in the transmission line. Positioning of valves is accomplished by the remote control system described.


PROFITABLE APPLICATIONS FOR SYNCHRO-SCAN SUPERVISORY CONTROL
WATER WORKS • SEWAGE TREATMENT PLANTS • CHEMICAL INDUSTRIES
WELL FIELDS • ELECTRIC POWER SUBSTATIONS • OIL AND GAS PIPELINES
INDUSTRIAL PROCESSES • RADIO AND TELEVISION BROADCASTING STATIONS
A TYPICAL SYSTEM
DISPATCHING CENTER
FLOW TELEMETERING
BUTTERFLY VALVE CONTROL
WELL FIELD PUMP CONTROL
BOOSTER STATION PUMP CONTROL
TANK LEVEL TELEMETERING

TYPICAL SYNCHRO-SCAN SUPERVISORY SYSTEM

Where reservors are below the treatment works and the water must be pumped, control of the pumps is accomplished by a supervisory control system in accord with the desires of the operator.

Levels in wells are controlled only through control of the operation of pumps which draw from underground sources. This too can be accomplished by use of a remote control system.

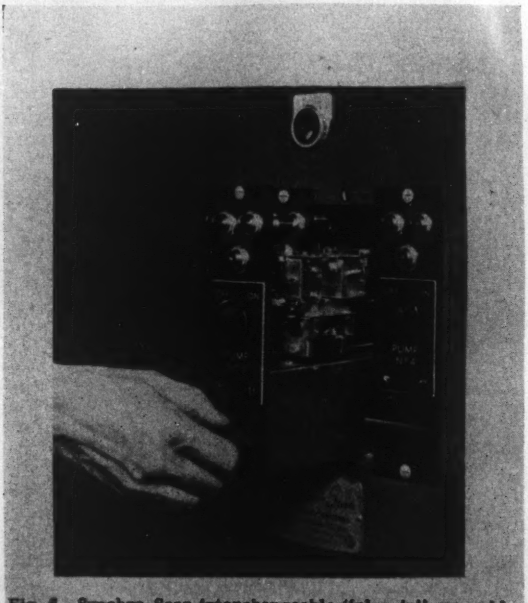


Fig. 6. Synchro-Scan interchangeable "plug-in" assembly.

As indicated, rate of flow or discharge, either by gravity or by pumps, is the most common control effected on the source of supply. It is possible to control flow rates at predetermined values, on a time-cycle basis (both on-off and rate variation) or in accord with the needs of the system.

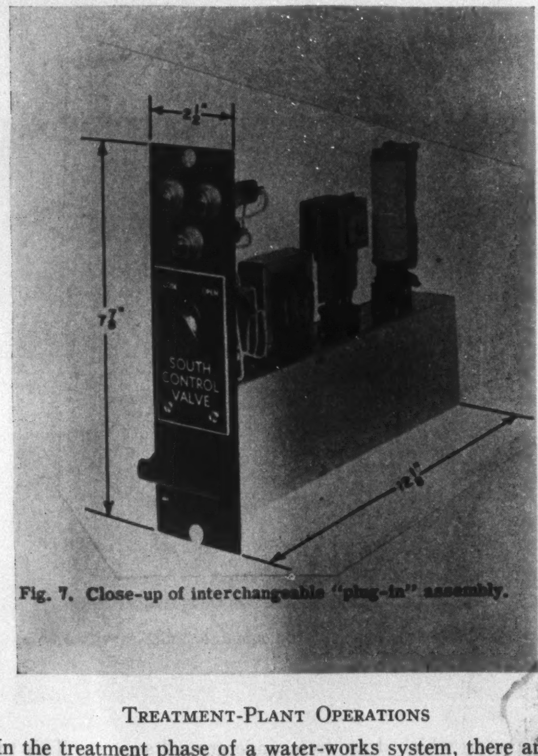

$2\frac{1}{2}''$
$7\frac{7}{8}''$
$12\frac{1}{8}''$
CLOSE
OPEN
SOUTH CONTROL VALVE

Fig. 7. Close-up of interchangeable "plug-in" assembly.

Treatment-Plant Operations

In the treatment phase of a water-works system, there are three general processes that require control to some degree. These are: chemical treatment (coagulation, softening, pH adjustment, stabilization, taste and odor control); filtration, and disinfection (chlorination)—(Fig. 8).

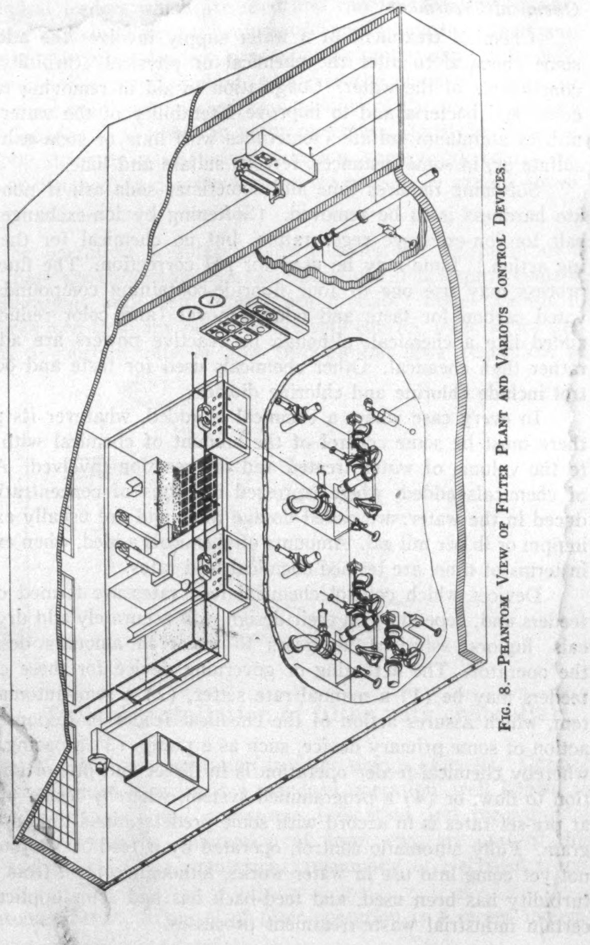


FIG. 8.—PHANTOM VIEW OF FILTER PLANT AND VARIOUS CONTROL DEVICES.

Chemical Treatment

Chemical treatment of a water supply involves the addition of some chemical to alter the chemical or physical (turbidity, color) constituents of the water. Coagulation to aid in removing turbidity, color, and bacteria and to improve filterability of the water usually utilizes aluminum sulfate (sometimes with lime or soda ash), ferric sulfate or, in some instances, ferrous sulfate and lime.

Softening requires lime and sometimes soda ash if non-carbonate hardness is to be removed. (Softening by ion-exchange utilizes salt for ion-exchange regeneration, but no chemical for the softening action.) Lime may be used for pH correction. The fluoridation process may use one of four fluoride-containing compounds. Activated carbon for taste and odor removal (and color reduction) is added like a chemical, although its reactive powers are adsorptive rather than chemical. Other chemicals used for taste and odor control include chlorine and chlorine dioxide.

In every case where a chemical is added, whatever its purpose, there must be some control of the amount of chemical with respect to the volume of water treated and the reaction involved. Amounts of chemicals added, when expressed in terms of concentration produced in the water, are called dosage rates and are usually expressed in ppm or lb per mil gal. Amounts of chemicals added, when expressed in terms of time, are termed chemical feed rates.

Devices which control chemical feed rates are termed chemical feeders and, depending on their design, will accurately add dry chemicals, liquors, solutions, or gases to water in amounts desired by the operator. The actuating or governing device for these chemical feeders may be (1) a manual rate setter, (2) a semi-automatic system, which assures action of the chemical feeder in response to the action of some primary device, such as a pump, (3) a pacing system, whereby chemical-feeder operation is in direct and proportional relation to flow, or (4) a programmed system, whereby feeder operation at pre-set rates is in accord with some predetermined time-cycle program. Fully automatic control, operated by a feed-back system, has not yet come into use in water works, although control from effluent turbidity has been used, and feed-back has had some application in certain industrial waste-treatment processes.

Chemical feeders which are used and can be controlled as outlined above include all types: volumetric and gravimetric (belt and loss-in-weight) solution feeders, proportioning pumps and gas feeders.

Whatever the chemical used, whatever the chemical feeder, or whatever the control system used, transmission of the control impulse from one location to another can be by pneumatic signal for distances up to 1,500 ft, or by telemetering or remote supervisory control regardless of distance, as described under the section on supply above.

Filtration

In the operation of filters, sometimes termed the purification process, there are certain factors and operations that require control. These operations and their control are probably better known to water-works men than any other. Filter rate control, by a device that maintains a constant rate of flow through the filter regardless of head loss, is a standard operation in filter plants (Fig. 9). Control of wash-water rates likewise is a standard operation, well known to water-works engineers and operators. Indication and recording of loss of head, flow rates, summation of flows, etc., are part of this control and utilize direct connections, pneumatic or electrical transmission.

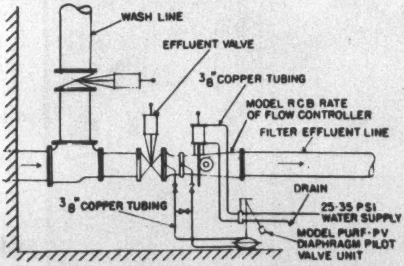

WASH LINE
EFFLUENT VALVE
3/8" COPPER TUBING
MODEL RCB RATE OF FLOW CONTROLLER
FILTER EFFLUENT LINE
DRAIN
3/8" COPPER TUBING
25-35 PSI WATER SUPPLY
MODEL PURF-PV DIAPHRAGM PILOT VALVE UNIT

Fig. 9. Typical installation of filter rate controller.

Automatic central control of filter operation is a recent innovation in filter control. In this system, electric-pneumatic transmission is used from a central control panel to the individual filters (Fig. 10).

This automatic control system works in this manner: When the loss of head on a filter reaches a predetermined level, a sentinel alarm light, buzzer or bell advises the operator of the condition of the filter. The operator pushes a button and the back-wash cycle is instituted. A back-wash timer provides two or more back-wash rates: an initial low rate, to break the sand surface, expel air and provide maximum scrubbing action between sand grains; a high rate follows,

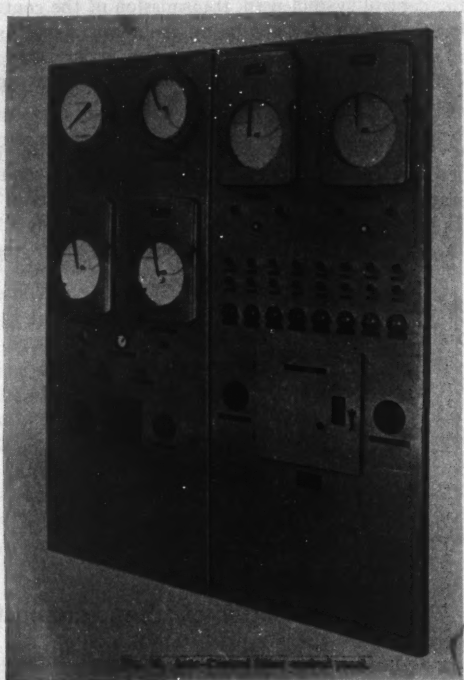


Fig. 10. [illegible]

fully expanding the bed to flush out the dirt; a low rate then follows, to allow the sand to classify as it settles out.

Back-wash rates may be varied, as to intensity and duration, from the central control panel, and the system can be adapted to surface-wash arrangements. Also manual variation is possible for the rate of operation of individual filters.

This system can be easily adapted to fully automatic control, if the operator desires. Control of the backwashing cycle can be initiated directly from the loss-of-head sensing element, by simply bypassing the manual starting button. This has been done at several installations, notably in Mexico, in Ardmore, Okla., and at the Gulf Oil plant in Port Arthur, Tex.

With the development of automatic turbidity-determining and recording apparatus, there is no reason why fully automatic filter-plant operation cannot be performed on the feed-back (automation) principle from turbidity in the effluent and loss of head in the filter. Such an installation has been in operation in Vallejo, Cal. In this country at present there seems to be a hesitancy on the part of engineers to adopt automatic operation. There still exists a belief that an operator should observe the backwashing operation; hence the use of the sentinel alarm and manual starting button.

Disinfection

Out of some 17,000-plus water supplies in the United States, 6,137 use disinfection. Practically all of the plants use either chlorine or hypochlorite, with a majority using chlorine.

No matter what chemical is used, actual addition of the chemical is by a chemical feeder (gas feeder for chlorine, proportioning pump for hypochlorite), and these chemical feeders which control the rate of addition may be controlled as described before—*i.e.,* manually, semi-automatically or step-wise, paced by flow or programmed (Fig. 11). Ultimate control in operation is according to the residual chlorine content produced, and this involves rate setting by the operator. Fully automatic control, using feed-back from the residual chlorine content, has not yet been perfected, although experimental studies now under way indicate its possible future adoption.

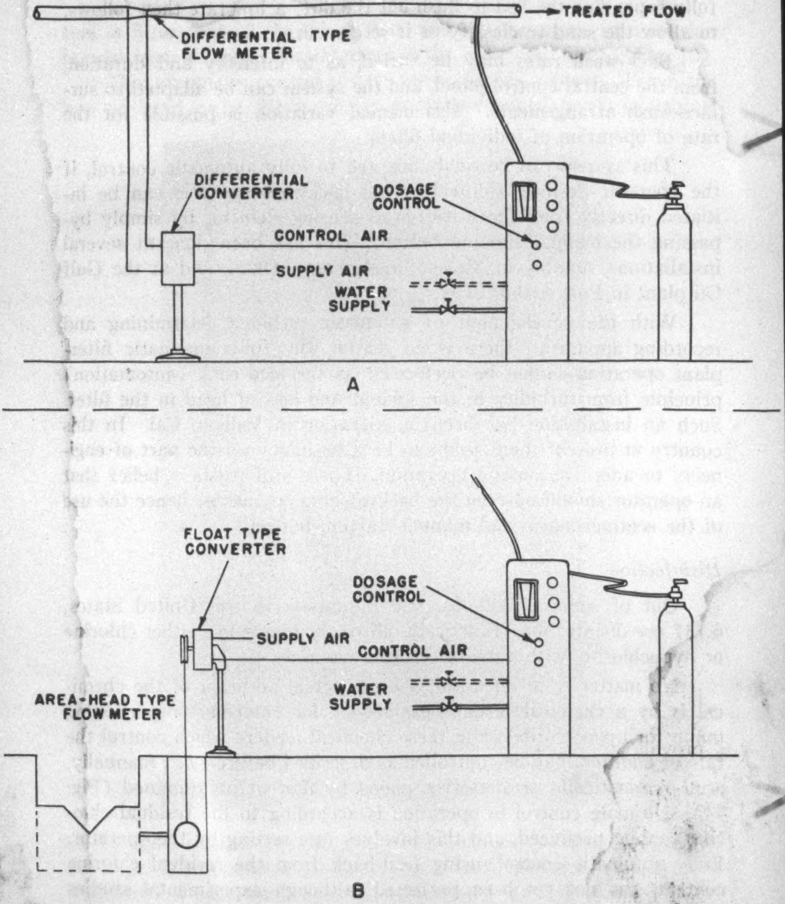

TREATED FLOW
DIFFERENTIAL TYPE FLOW METER
DIFFERENTIAL CONVERTER
DOSAGE CONTROL
CONTROL AIR
SUPPLY AIR
WATER SUPPLY
A
FLOAT TYPE CONVERTER
DOSAGE CONTROL
SUPPLY AIR
CONTROL AIR
WATER SUPPLY
AREA-HEAD TYPE FLOW METER
B

FIG. 11.—PROPORTIONAL PACING OF CHLORINE FEEDER (PNEUMATIC).

DISTRIBUTION

In the distribution system two things must be provided: (1) pressure and (2) quantity or flow. The former involves pumps and pumping or gravity, and the latter involves capacity of pumps and lines, and head. Obviously the factors to be controlled are pressure and quantity. When pressure is created by gravity from a distributing reservoir, it is the level in the reservoir which is controlled. This control involves a sensing element (float, diaphragm, bubble pipe, etc.), transmission to the controlling device, and the control device itself, which may be a valve or pump. Pressure created by pumps is controlled by pressure-sensing devices (Bourdon tube, for example), from which is transmitted a signal to an instrument and control panel. From this control panel, in turn, goes a signal to the control device, usually a pump.

Pump controls, therefore, are the principal control systems used in a distribution system. So-called "automatic" pump control falls into five categories: time-cycle, pressure, level, pressure-flow, and remote supervision. The first-named of these is programmed control; the second, third and fourth are true automatic (feed-back) control, in that the result of the operation actually controls the operation; the last-named, remote supervision (or supervisory control), can involve any degree of control (*i.e.*, manual, semi-automatic, step, programmed or automatic).

Time Cycle

Time-cycle control (programmed) involves starting and stopping of pumps on some predetermined time relationship. Adjustments may be provided, to change the cycle for seasonal or weekly variations. Sometimes simple pressure control is used with time-cycle control to provide for unusual conditions, such as low suction head or fire flows.

Pressure

The simplest pressure control is a pressure switch on the pump discharge line, this switch being adjusted to close the pump circuit when the pressure falls below a selected minimum value. If the switch is equipped with a differential sensing device, the contact can be made to open when the pressure reaches a selected maximum value. This is simple on-off control—not too accurate, since pressure drop in lines and fittings influence the sensing element.

Level

Where suction is taken from a ground-level reservoir and the pumps discharge into an elevated storage tank or closed section of the distribution system, more responsive control can be had by using the level of the water in the tank, instead of pressure. This method may be applied to any number of pumping units, provision being made to start each pump at some predetermined minimum level and to stop them either successively or all at once at some predetermined high level.

Level controls may be of two forms, depending on the distance from tank to the pump station. If the distance is short, any type of level-sensing unit may be used (float switch, air bubbler, electronic or resistance probes, diaphragm bell-operated indicator and/or recorders equipped with adjustable contacts).

When the tank and pumps are some distance apart, a pressure gauge (graduated in feet) or altitude gauge may be connected to the standpipe to indicate tank levels, and this gauge may be equipped with electric contacts to start and stop the pump at predetermined levels. If appreciable distances between tank and pumping station are to be overcome and if more precise control is required, a Chronoflo telemetering system is recommended.

Pressure-Flow

One system of pump control combines both pressure and flow information. Developed and patented by Marsden C. Smith, it is marketed under the name "Pressureflo" (Fig. 12). It has the widest range of usefulness of any of the pump-control systems.

Provision is made for metering the flow and for sensing the pressure in the system. Usually some form of initiating control is employed—*e.g.*, low-pressure switch on the pump discharge line or a minimum level contact in the elevated tank. Once the pump is started, it will continue to run as long as the flow remains above some predetermined minimum and/or the pressure remains below some pre-set maximum value. This system can function equally well with ground-level storage or elevated tanks.

Remote Supervisory Control

In many instances it is desirable to control the operation of pumping equipment at a remote location from a central station. Such a system is termed "Supervisory Control". For this purpose either telemetering or Synchro-Scan can be used. The latter is much more versatile than the former. Controls which can be effected include selection of pump unit, start-stop of pump, report back of condition, reset equipment for next operation, vary pumping rates, indicate valve positions, "jog" valves open or shut, etc. With the Synchro-Scan system it is possible to obtain any degree of control for pumps or other equipment.

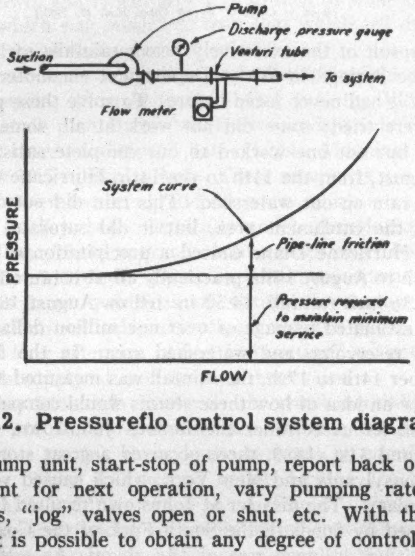

Pump
Discharge pressure gauge
Venturi tube
Suction
To system
Flow meter
System curve
PRESSURE
Pipe-line friction
Pressure required to maintain minimum service
FLOW

Fig. 12. Pressureflo control system diagram.

SUMMARY

In the operation of water-works systems there are many individual functions and actions that require control. There is no one single "package" which can be utilized for every type of control problem. From the discussion in this paper it is obvious, however, that there are several standard control systems and equipment which can be integrated into a water-supply system, to obtain the control desired for any particular operating function.

THE OPERATION OF SLOW SAND FILTERS DURING THE 1955 FLOODS

BY JOHN P. LYNCH*

[Read at Chemists' Round Table, Nov. 17, 1955.]

As a result of the excessively heavy rainfalls of last August and October, the Springfield Water Department encountered many problems which it had never faced before. To solve these problems, many methods were tried; some did not work at all, some were partially successful, but not one worked to our complete satisfaction.

In August, from the 11th to the 14th, Hurricane Connie dumped 9.43 in. of rain on our watershed. This rain did not do any physical damage to the catchment area, but it did saturate the ground, so that when Hurricane Diane caused a precipitation of 17.36 in. from August 17th to August 19th, practically all of it ran off the watershed. Of this 17.36-inch rainfall, 14.50 in. fell on August 18th. This storm caused an estimated damage of over one million dollars to the filtration plant, reservoirs, and watershed area. In the four-day period from October 14th to 17th, the rainfall was measured at 15.47 in.

To give an idea of how these storms would compare with another great storm, let us consider the famous Johnstown, Pa., flood. On May 30th and 31st, 1889, there occurred a great storm over a large part of Pennsylvania and New York, which caused very high floods in many streams. The disaster at Johnstown resulted from this storm. It was caused by floods in the South Fork of the Conemaugh River, a stream with a drainage area of 48.6 sq mi. An estimate, made by an investigating committee of the American Society of Civil Engineers, placed the maximum rate of flow at about 155 mgd per sq mi. The rainfall amounted to 6 to 8 in. on May 30th and 31st, the estimate being that for several hours rain fell at the rate of two-thirds of an inch per hour. The estimated rate of flow would be equal to one-half of this. To compare this to the floods which occurred on our watershed, our drainage area is approximately 45.8 sq mi, as compared to

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*Chemist, Water Department, Springfield, Mass.

Johnstown's 48.6 sq mi. The maximum rate of flow on our watershed was computed to be 262 mgd per sq mi of watershed during the August storm, and 227 mgd per sq mi of watershed area during the October flood. I realize that a comparison of these two floods is not valid, because the death and destruction caused by the Johnstown flood were due to the collapse of a dam. However, the Johnstown flood is best known, and it will give you an idea of what can happen with a rainfall which was much less than that which fell during each of the three storms of this year.

For those who are not familiar with the Springfield system, let me briefly summarize its main features (see Fig. 1). We have two reservoirs, one at Borden Brook which impounds 2.5 billion gallons of water. This reservoir empties into Cobble Mountain Reservoir which impounds 22.5 billion gallons. These reservoirs are located in sparsely settled watershed areas, and the water which is impounded is of a very high quality, both chemically and bacteriologically, under ordinary conditions. These reservoirs hold enough water for the needs of Springfield for 750 days. However, since the operation of the powerhouse uses large quantities of water, the average retention period, during which natural purification may take place, is roughly one year. This long retention period is "hurting" us now, because we have a year's supply of mud in these reservoirs.

From Cobble Mountain Reservoir the water normally is taken from an outlet 120 ft below the surface, through a tunnel to the powerhouse. After passing through the turbines, it empties into an intake reservoir. There is a second outlet, located about one mile to the north, which is 220 ft below the surface of Cobble Mountain Reservoir. The water flowing from this outlet goes through a gorge and into the intake reservoir, without passing through the powerhouse. At the lower end of the intake reservoir, the tunnel to filtration plant is located, and through this flows the water needed to satisfy the city's demand. The excess flow from the powerhouse goes over the dam and down the river. From this inlet, the water going to the filtration plant passes through a tunnel to the settling basin, which holds 45 mil gal. From here, the water is piped to 14 slow sand filters, which have eight acres of filtering surface. After filtration, water goes to a storage basin at Provin Mountain, which holds

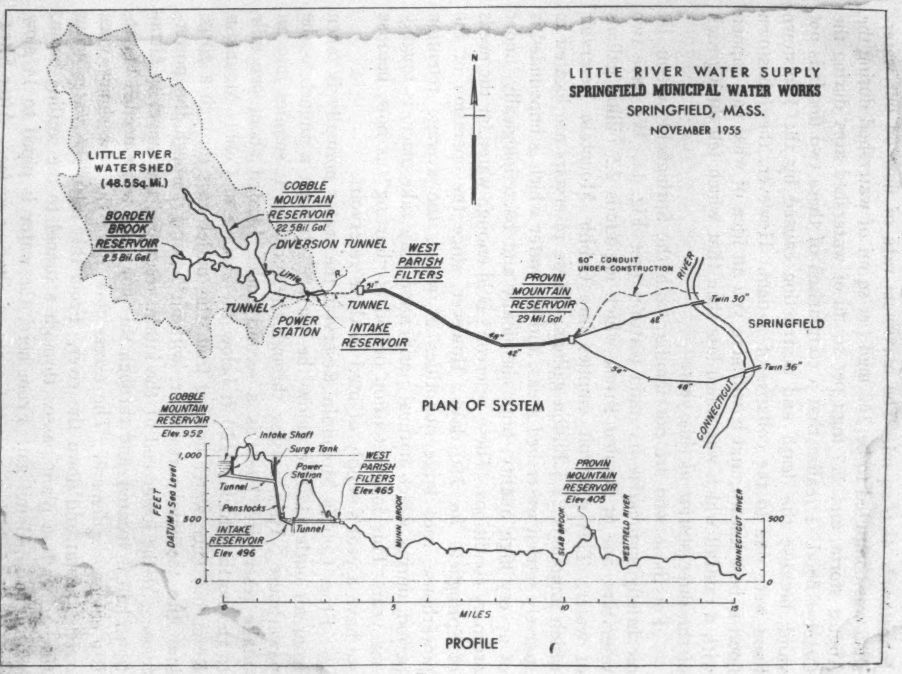
LITTLE RIVER WATER SUPPLY
SPRINGFIELD MUNICIPAL WATER WORKS
SPRINGFIELD, MASS.
NOVEMBER 1955
N
LITTLE RIVER WATERSHED (48.5 Sq. Mi.)
COBBLE MOUNTAIN RESERVOIR 22.5 Bil. Gal.
BORDEN BROOK RESERVOIR 2.5 Bil. Gal.
DIVERSION TUNNEL
Little R.
TUNNEL
POWER STATION
TUNNEL
INTAKE RESERVOIR
WEST PARISH FILTERS
31"
48"
42"
PROVIN MOUNTAIN RESERVOIR 29 Mil. Gal.
60" CONDUIT UNDER CONSTRUCTION
RIVER
48"
54"
48"
Twin 30"
Twin 36"
SPRINGFIELD
CONNECTICUT
PLAN OF SYSTEM
COBBLE MOUNTAIN RESERVOIR Elev. 952
Intake Shaft
Surge Tank
Tunnel
Power Station
Penstocks
WEST PARISH FILTERS Elev. 465
INTAKE RESERVOIR Elev. 496
Tunnel
FEET
DATUM = Sea Level
1,000
500
0
MUNN BROOK
SLAB BROOK
PROVIN MOUNTAIN RESERVOIR Elev. 405
WESTFIELD RIVER
CONNECTICUT RIVER
500
0
0
5
10
15
MILES
PROFILE

Fig. 1.

29 mil gal of water. There it is held until needed for consumption.

On the afternoon of August 18th, a small brook which flows through the filtration plant broke loose from its channel, and on three occasions during the next 18 hours, a foot of water flooded the filters. Some of this water went through the manholes on the tops of the filters, making it necessary to shut down four filters because of the large amount of clay that was washed into them. The water entering the plant was of such poor quality that the inlet from the intake reservoir was closed and the water in the settling basin was used. During the night of the 18th, the telephone service was disrupted, the roads were washed out and we were isolated. We had no knowledge of what was happening elsewhere in the system.

On Saturday morning, August 20th, a helicopter was sent in to find out if the filters were still in operating condition. We were informed that the surface supply of the town of West Springfield was completely washed out and that their well system was inoperative, due to inundation of the pumps. We were told also that the connection to our system had been opened and that they were drawing 3 mgd from the Springfield system. Because of this and because there had been several breaks in the Springfield distribution system, the consumption of water was greater than usual. This increased consumption caused the amount of water in storage at the Provin Mountain Reservoir to fall to a dangerous level. Consequently, it was necessary to open the inlet to the settling basin and allow the water from the intake reservoir to pass through to the filters. This water had a turbidity of 100 ppm and a true color of 35 ppm. Since the settling basin held only 25% of its capacity, the use of coagulant was deemed unwise. It was felt that the retention period was not sufficiently long to give adequate flocculation and settling and, therefore, the floc would be carried over into the filters and would clog them more than the turbidity-causing matter in the water.

The effluent waters were checked every four hours for turbidity. The effluents of the filters had a color of 13 ppm and a turbidity of zero. The rate of filtration was approximately 6.5 mgd per acre of filtering surface from the nine filters that were operating. This is higher than the recommended maximum, but since there was no choice it had to be done.

The diversion gates of Cobble Mountain Reservoir were opened, because the powerhouse was inoperative, due to landslides and flooding. The water taken through these gates was drawn from 220 ft below the surface of the reservoir and was not affected appreciably by the heavy rainfall. The true color of this water was 17 ppm and the turbidity was 3 ppm. However, since Cobble Mountain Reservoir was spilling, the turbid surface water mixed with the clear water from the bottom of the reservoir, and the water that was available for filtration was of poor quality. After four days, the reservoir stopped spilling and the clear water started reaching the filters. This water had a turbidity of 5 or 6 ppm and a true color of 17 to 20 ppm.

The bacteriological samples which were collected during the period immediately following the flood were positive for coliform organisms in a larger percentage than is normal. However, the results obtained were not typical for *E. coli*. The organisms causing the gas were very slow in fermenting the lactose broth. Many of the tubes which were positive at the end of the 48-hour incubation were negative four hours earlier. The 37° C. and the 20° C. standard plate counts were not affected by the floods. Since the Springfield Water Department under ordinary conditions does not chlorinate, these positive results caused concern. Samples were checked for coliform content every eight hours. While the percentage of positive confirmed samples was many times higher than usual, it did not exceed the standards as set by the U. S. Public Health Service.

On August 24th, deep samples were collected from Cobble Mountain Reservoir, and it was found that the turbidities increased from 50 ppm at the surface to 120 ppm at 48 ft and decreased to 100 ppm at 96 ft and to 6 ppm at 106 ft. Sampling done weekly thereafter showed that samples collected at the surface were approximately the same until the second flood on October 15th. The turbidities at depths of 50 and 70 ft ranged from 120 to 100 ppm until September 17th. During the period from September 17th to October 3rd, this turbid layer from 50 to 70 ft showed a considerable reduction in the turbidity. On October 3rd, these turbidities were read as 50 ppm.

This turbidity was caused by a large landslide which came from the spillway of Borden Brook Reservoir. It is estimated that 80,000 cu yd of material were washed into Cobble Mountain Reservoir. It was clay-like in composition and was either colloidal or extremely close to a colloid in size.

On September 7th, the powerhouse was returned to operation and the outlet from Cobble Mountain Reservoir at the 120-foot level was used. Due to the construction of this outlet, much of the water drawn at this level was pulled down from the stratum where the turbidity was greatest. This water mixed with approximately 40 mgd of clear bottom water from the diversion gates. Since the quality of the mixed water was still poor, the intake gates to the plant would be closed while the powerhouse ran during the day, and at night, when the powerhouse was not in operation and we were able to get the largest percentage of the clear bottom water, the gates to the plant were opened and the settling basin was filled for the next day's run. In this way, we were able to get water for filtration which had a turbidity of 15 to 20 ppm and a true color of 25 to 30 ppm. The filters were able to handle water of this quality adequately. The effluent water had a color of 11 or 12 ppm and a turbidity of zero.

Those filters which were most heavily flooded when the brook through the plant broke loose were cleaned by lowering the water level in the filter until about 6 in. of water remained over the sand, then reversing the flow, and having a crew of men break up the clay seal on the surface of the sand with stiff highway brushes. The clay was re-suspended and floated out the waste water drain. This method of cleaning a filter worked surprisingly well, as most of the material which washed in was caught on the surface of the filter. Fortunately, most of the filters had been in operation long enough before the flood, so that a good Schmutzdecke had formed, and this was able to prevent any great degree of penetration of the clay.

During this period, the use of coagulants was considered, but since the filters were removing the clay without any apparent clogging, it was decided to allow them to handle the turbidity as long as they would continue to do so.

Because it was believed that dilution would reduce the turbidity in the reservoir, before sedimentation would eliminate it, a close watch was kept on all the influent streams. Good clear water flowed in all of them, and when it entered the reservoirs, it would drop down below the surface, leaving a definite line of demarcation between the turbid surface water and the clean influent water.

The real "backbreaker" came when the October rains arrived. This rainfall of 15.47 in. did not do any physical damage to the plant or watershed. However, it did create many new problems in connection with the quality of the water. The color of the water reaching the filters increased by 10 ppm per day, until a maximum of 50 ppm was reached. After six days, the color dropped to 46 ppm and has held at this figure since that time. The turbidity increased to 22 ppm and, after five days of this, it decreased for five days until it had dropped to 10 to 12 ppm, and it has held at this figure ever since. The color of the filtered water increased from 11 ppm to a maximum of 23 ppm. The turbidity of this water was one part per million. This filtered water continues to show the same turbidity.

Probably one reason why some of the turbidity was able to penetrate the filters was that all were cleaned during a short period of time. The loss of head on the filters was increasing at the rate of approximately 0.5 ft per 24 hours. The labor situation was quite acute at this time, since it is difficult to get men to travel to the filter plant, due to its isolated location. At that time, several men who ordinarily work at a local factory, which was temporarily shut down, were hired, and they did an excellent job of cleaning the filters. During the period from Oct. 20 to Oct. 30, twelve filters were out of operation at one time or another for cleaning. Of the other two, one was down at the time of the flood for cleaning and the other was running to the drain after being resanded. During the greater part of this period the plant was running with 9 to 12 filters in operation. Due to the fact that all had been cleaned during such a short period, a good Schmutzdecke had not had time to form on these filters before they were placed back in operation under an overload. An attempt was made to form an artificial Schmutzdecke by adding a floc directly to two of the filters. The effect of this floc was only temporary. As soon as these beds are out of service, a careful inspection will be made to determine if the floc became saturated with color- and turbidity-causing material, or if it broke down, went back into solution and passed through the filters.

On October 15th, the powerhouse started operating 24 hours per day, in order to lower the level of the water in the reservoir, so that, in the event of another storm, the rainfall could be caught and held back, to prevent any further damage to the paper mills farther down the river. These mills were damaged heavily in the first flood, and the repairs which they had made were washed out during the second flood. Of course, the overflow from the reservoir was only a small part of the water which did the damage, but any water which could be held back would help them. The power company is having trouble in lowering the elevation, because as soon as it drops a couple of feet, another storm hits, and the reservoir fills up again. One such storm occurred on October 30th, with a rainfall of 3.58 in.

The diversion-tunnel gates to the reservoir were closed, because the power company was operating 18 to 24 hours per day and the 40 mil gal of clear bottom water was not sufficient to dilute the water coming through the powerhouse. Consequently, the water reaching the filters came mainly from the most turbid stratum of the reservoir.

On October 18th, coagulation jar tests were run, to determine how effective coagulation would be. It was found that alum and lime would floc and settle, but only after standing for several hours. It is believed that the settling basin is "short-circuited", so that effective settling time is of short duration. This basin is shaped more or less like a four-leaf clover, with the influent water entering one of the upper leaves and following its edge around to the stem and out of the basin.

After experimenting with various coagulants, it was found that activated alum and sodium aluminate produced a floc which formed rapidly and settled quickly. However, when these chemicals were applied to the basin, the reduction in turbidity and color was only 30%, despite the formation of an excellent floc. The amounts required were 2.5 grains per gallon of activated alum and 2 grains per gallon of sodium aluminate. This means that for 35 mil gal of water it would be necessary to add approximately 11 tons of chemicals per day. Since a complete treatment would be too costly, and because, if a good floc were formed and it settled completely, the settling basin would fill up with floc in short order, it was decided that spot treatments might help. Consequently, every four hours, a high dosage of chemicals was added to a million gallons of water. It was believed that if the color and turbidity could be reduced on every fourth million, it would help by dilution of the other three untreated million. However, this was not successful or, if it was, its effect was not apparent. Also, some of the industrial plants in Springfield became quite alarmed at the possibility that some of the aluminum might stay in solution and interfere with their manufacturing processes. A careful check of the aluminum content of the filter effluents proved their fears were groundless.

Next, it was decided to use chlorine as a bleaching agent to oxidize the dissolved organic matter. A portable trailer-chlorinator was obtained from the State Department of Health, and this was set up to treat the effluent of one set of four filters. It was impossible to set the chlorinator where chlorine could be added to the effluents of all 14 filters. Under normal circumstances, Springfield is reported to be the only municipal surface supply which is not chlorinated; therefore, provisions have not been made for the addition of chlorine at any point in the combined effluent line. The effect upon the effluent of these four filters is sufficient to give a 4-ppm reduction in the combined effluent of all 14 filters. This reduction gives a filter effluent of 19-ppm color.

Just to keep things from becoming monotonous, for a few days after the second flood, the iron content of the water in the reservoir was increased to 0.5 ppm. However, since the maximum reaching the filters did not exceed 0.3 at any time, steps to correct this condition were not deemed necessary.

Also, the pH of the raw water dropped from a normal of 6.3 to 6.1, and the effluent water dropped from a normal of 6.1 to 5.9. However, aeration at Provin Mountain Reservoir increases the pH to 6.5.

A survey of the streams entering Cobble Mountain Reservoir showed that many of the streams which rise in the swampy areas of the watershed have colors as high as 120 ppm. The other streams all have colors over 40 ppm. On the basis of this information, it appears that these problems are going to be with us for a long time to come.

While the solutions which were used were not completely satisfactory to those of us who are concerned with the quality of the water, they evidently were adequate for the consumers who rely upon us for water, since no complaints have been received whatsoever.

EXPERIENCES WITH PUBLIC WATER-SUPPLY DAMAGE IN THE CONNECTICUT FLOOD DISASTER OF 1955

BY WARREN J. SCOTT*

[Read Nov. 17, 1955.]

There are outlined in this discussion some of the experiences of the sanitary engineering staff of the Connecticut State Department of Health in connection with the flood disasters in the state in 1955. All of the experiences are with regard to the August flood, but reference is made to the use of standby power during the October flood. By and large, damage to Connecticut water supplies in the October flood was negligible as compared to the August flood. The staffs of the Connecticut water utilities, publicly and privately owned, were in the thick of the disaster and the officials in charge of the systems in the worst affected areas have kindly summarized for the writer the major damage to their respective systems. They themselves could undoubtedly contribute greatly to the general pattern of handling water-supply emergencies through their own extensive experiences during the recent disaster.

GENERAL

At 5:40 A.M. on August 19, the writer received a telephone message from Dr. Harold S. Barrett, deputy commissioner of health, to the effect that Civil Defense authorities were being called on the alert, because of the impending disastrous effects of the flood waters following the heavy rainfall. All of the available sanitary engineers were called by telephone and reported in to the office at 8:00 A.M. Two of the sanitary engineers were unable to get out of their homes because of the flood conditions around their homes, but they were able to be on hand the following morning.

Plans were laid out for field assignments in the flood areas as rapidly as plans could be developed as to where to go and how to get there. Many roads were impassable because of flood conditions or demolished bridges. From then on, the field activities of the sanitary engineers in the department, insofar as public water supplies were concerned, were handled by the sanitary engineering bureau as follows:

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Frederick O. A. Almquist, principal sanitary engineer, was assigned to Putnam; LeRoy W. Van Kleeck, principal sanitary engineer, and Charles A. Jaworski, senior sanitary engineer, were assigned to Torrington; Leslie K. Sherman, principal sanitary engineer, was assigned first to the Naugatuck Valley area and was active principally in Naugatuck, Seymour and Ansonia. Mr. Sherman also worked to some extent in Winsted and in Waterbury. David C. Wiggin, principal sanitary engineer, was assigned to Waterbury. Richard S. Woodhull, senior sanitary engineer, was assigned to Winsted and New Hartford; he had some assistance from Mr. Sherman and also in the first part of the disaster period from Richard S. Green, senior sanitary engineer of the United States Public Health Service, who was assigned to Connecticut at our request. Mr. Green later worked with the United States Army Engineers in connection with appraisal of flood damage.

On August 19, the writer made a radio broadcast, advising officials in charge of public water supplies that, as a precautionary measure, they should increase chlorine residuals on their water-supply systems so as to offset the effects of the heavy runoff that had occurred. This was done during the period when increasing damage was being registered on many water-supply systems. Also, it should be understood that the main damage to public water-supply systems in the August floods was in the valleys of the Quinebaug River in northeastern Connecticut, the Farmington River in northwestern Connecticut, and the Naugatuck River in central Connecticut; water supplies in other areas of the state were not hard hit.

The October flood was principally felt in the southwestern corner of Connecticut. Fortunately, there was little damage to public water-supply systems in the October flood, except for a few water-main breaks, but the tremendous amount of rainfall in the October flood in this particular area of the state did pose a serious threat to some water-supply dams.

RAINFALL

Table 1 is included to summarize some of the record rainfall during the August and October floods. It is of interest that in many

TABLE 1.—RAINFALL IN INCHES DURING AUGUST AND OCTOBER FLOODS, 1955.

Date, 1955	*Hartford (Windsor Locks, Bradley Field)	Hartford (Brainard Field)	Hartford Metropolitan District (Phelps Brook)	Torrington	Putnam	Norwalk
August 12	2.08	2.17	2.81	1.09	2.80	
August 13	1.64	0.72	2.79	3.11	2.90	
August 14	0.30	0.22	3.03	0	0.58	
August 15	0	0	0.10	4.45	0	
August 17	0.43	0	0	—	0	
August 18	6.27	2.60	1.04	3.77	2.90	
August 19	7.70	5.25	12.77	9.52	5.75	
August 20	0	0	2.11	0	3.00	
Total August	21.87	13.68	27.43	23.05	20.78	
Normal August	4.29					
October 15						**10.79
October 16						** 2.83

*Weather Bureau, official station.

**Note: The 2-day total is correct, but the division between the 2 days is inaccurate, as it is based on intermittent readings. About 11 in. of rain fell in less than a 16-hour period.

affected areas of the state in August, there was a two-day rainfall of approximately 14 inches or higher. The distribution of the rainfall over the state was very variable during the critical periods. For example, at Brainard Field in Hartford only 7.85 in. were recorded in a two-day period, whereas the official Hartford Weather Bureau station in Windsor Locks, about 12 miles away, recorded 13.97 in. on the same two days.

It is noteworthy that the total rainfall in August for much of the state was about ½ the normal rainfall figure for an entire year.

It is also of interest that in Norwalk there was a total of 13.6 in. of rainfall in a two-day period in October, but much more striking is the record of almost 11 in. of rainfall in a period of less than 16 hours at Norwalk. During the August flood, a 24-hour rainfall of 12.77 in. was recorded on the Hartford watershed.

Looking back over the rainfall records in Connecticut, the writer has noted that at New Haven, where the records are available beginning in 1804, no monthly rainfall has ever equalled the August rainfall of 1955 that occurred in many sections of the state, ranging as high as 27+ in. In New Haven there was an August rainfall of 12.99 in. in 1874 and a July rainfall of 17.08 in. in 1889. In Hartford, apparently the highest record rainfall, going back to the beginning of records in 1868, was in September, 1938, when there was a monthly rainfall of 14.59 in.

These figures all indicate that the rainfall of 1955 was unprecedented.

FAILURE OF PUBLIC WATER-SUPPLY SYSTEMS

The most serious effect of the floods on public water supplies was the extensive number of breaks that occurred in main supply lines and piping throughout distribution systems. As a result of the havoc wrought by the flood, there was virtually 100% interruption in water service in the following communities: Seymour, Beacon Falls, Torrington, Winsted, Putnam, Avon and Collinsville, and some of them were without water for periods of several days to over a week. Supplies were greatly depleted in Waterbury, Naugatuck and Unionville, and some parts of these communities were without water for one to several days.

Fortunately, except for two or three flooded wells which were in use on public water-supply systems and some damage to small dams on the Torrington water supply, the sources of supply of most of the communities were undamaged. Except for one or two isolated instances of trouble with chlorination plants, the treatment facilities were intact. In one case, a chlorinating plant was partially washed out by the effect of the flood waters, and repairs had to be made.

LOSS OF POWER

Electric service was interrupted in some communities in both August and October floods. Fortunately, most of our water systems are supplied by gravity. Also, where there are electrically operated pumps on chlorinating plants, there are standby hydraulically operated pumps, to function in case of failure of electric power. It was found that the tremendous flow of water passing through the supply main due to breaks so increased the chlorine demand that the hydraulically operated pumps could not keep up with the chlorine demand in two or three instances.

SUMMARIZED DETAIL ON SUPPLIES SUBJECTED TO MAJOR DAMAGE

To get some idea of the extent of the damage, the following data relative to some of the worst damaged systems are summarized on the basis of information furnished by the utility officials. The list below is by no means complete and does not include several other badly damaged utilities, such as those in Ansonia, Derby, Collinsville, Unionville and others. Also, losses of hydrants, house services, meters, etc., are not listed. The purpose of this limited list is to give some idea of the character and extent of damage.

Torrington

(Courtesy of Marshall Lawton, President, Torrington Water Co.). Two small reservoir dams were washed out, but fortunately these were not essential. One small supply intake reservoir was filled with silt and must be cleaned. One chlorinator house was practically demolished. Both the 12-inch and the 16-inch supply lines from Reuben Hart Reservoir were carried away at the first bridge crossing. Further down, 10-inch and 12-inch pipe crossings were broken. Both 20-inch and 24-inch pipes for a steel storage tank were broken. There

WARNING
BOIL DRINKING WATER

Due to a temporary emergency, all consumers of water from the public supply are hereby notified to boil all water used for drinking or cooking until further notice.

In some cities these notices were tacked up all over the community on telephone and electric light poles and other places. The radio stations did yeoman service, although some were temporarily out because of power difficulties. Handbills were prepared and distributed locally. Sound trucks were of help. Newspapers were, of course, of great assistance in keeping people informed as to progress and developments.

DISTRIBUTION OF DISINFECTING TABLETS FOR WATER OTHERWISE UNSAFE FOR DRINKING

Early in the disaster period the state department of health arranged with the State Office of Civil Defense to secure large supplies of iodine-compound tablets for water disinfection. These were secured from the Army. The tablets came in very small bottles of 50 each; there were 100 bottles in a small box, and there were four boxes, or a total of 20,000 tablets, in a small carton measuring 12 in. by 24 in. by 5 in. The bottle contained the following directions on it (presumably based on military use):

"Directions:

1. Add one tablet to canteen of water (1 qt.), replace canteen cap loosely to allow a little leakage.
2. Wait 5 minutes.
3. Shake thoroughly so that a little water leaks out and disinfects the screw threads. Then tighten canteen cap.
4. Wait 10 minutes before drinking, or adding beverage powders. If water is very cold wait 20 minutes.
5. If water is dirty or discolored, use 2 tablets."

Because of the ease of transportation and use, millions of these tablets were distributed to affected cities and towns. They were made available at temporary stations which had been set up in schools and elsewhere. These tablets were especially useful when electrical service was disrupted and many people were unable to heat water for boiling. The sanitary engineers of the state department of health assisted in making arrangements for distribution.

Use of Auxiliary Sources of Public Water Supply

This heading is listed as an important consideration in disaster-relief operations, but it so happened in this particular flood that no auxiliary sources of supply (except for limited amounts of hand- or truck-transported water) were placed in service. This was because the sources of public water supply were generally undamaged and the piping breaks were largely responsible for the trouble.

Approval of Temporary Sources of Drinking Water and Provision of Disinfection or Other Treatment for Such Sources

The National Guard set up a water-purification unit in Putnam, and the U. S. Army Engineers set up water-purification units in Torrington and Winsted. This was done in cooperation with the Civil Defense authorities. Each of these units had a capacity of 75,000 gal per 24 hours. Treatment consisted of pre-chlorination, coagulation, settling in small sedimentation tanks, and filtration through diatomite filters. The military had trained personnel who were thoroughly practiced in operating the units, and they were able to place them in operation in short order.

Sanitary engineers from the state department of health inspected the surroundings of the ponds which were used as sources of raw water. These treatment units were of great assistance. Where chlorinated water from the public water supply is available in the upper part of a supply line, it is often as easy to distribute water from such a point as to set up a purification unit, stationed at some other source, even though the latter station may be somewhat nearer from the transportation standpoint. Such transportation and distribution from the upper part of the supply line was arranged in one community.

In some places, drilled wells at schools or factories were unaffected by the floods and were known to be safe. They, therefore, served as sources of supply for filling up containers for distribution.

One factory well in Winsted and a school well in an outlying section in Torrington served as useful supplies.

The sanitary engineers from the state department of health assisted in passing on the safety of water supplies pressed into use.

TRANSPORTATION OF WATER AND DISTRIBUTION STATIONS

Milk-tank trucks were loaned for service in water transportation. Also, large milk cans were used for trucking in water. Directions had been distributed locally for cleaning and disinfecting gasoline- and oil-tank trucks, based on procedures previously tested out by the state department of health during the last war. It is not believed, however, that this particular type of truck was used in this emergency. Ready-mix concrete trucks and one or two other types of tank truck were used for water transportation.

Lister bags, which hold approximately 32 gal, were set up on tripods in some cities, and water could be drawn from them into containers brought by individuals. These Lister bags were secured from the Army through the office of Civil Defense. The state department of health arranged for transportation of these in several instances.

The sanitary engineers from the department tried to emphasize the need for using clean disinfected containers for carrying water, and assistance was rendered to promote this. High-test chlorine powder was used for disinfection of tanks and containers at distribution points. Clean metal containers of about 5-gal capacity, used ordinarily for ice cream, were made available for storage of water at distribution points in one community.

STEPS TAKEN TOWARD RESTORATION OF SUPPLY SYSTEMS

Early in the disaster, the writer, acting as state water coordinator, arranged with the Hartford Metropolitan District and the Civil Defense transportation officials for shipment of a 16-inch valve and four 12-inch valves to Winsted.

The State Office of Civil Defense had 10 miles of 8-inch, quick-coupling steel pipe distributed around the state, and much of this was put to good use. In Naugatuck, about four miles of this pipe were laid to replace broken pipes. Some utilities, such as those in Putnam and Unionville, used considerable lengths of quick-coupling, lightweight aluminum pipe for temporary repairs. Much of this pipe is available in Connecticut, being used for irrigation purposes; some of this pipe was sent to Winsted.

As usual, the officials of the utilities not affected seriously gave splendid cooperation in assisting the less fortunate. This assistance was rendered in part by loaning the services of pipe crews, and in part by loaning pipe and fittings. Among the utilities which furnished pipe crews were the Hartford Metropolitan District, the Bridgeport Hydraulic Co., the New Haven Water Co., the Greenwich Water Co. and the Birmingham Water Co. The Bridgeport Hydraulic Co. loaned the services of their sanitary engineer to the Torrington Water Co., and he greatly aided that company in connection with disinfection of mains. The New Haven Water Co. furnshed laboratory assistance to the Naugatuck Water Co., in addition to the examinations by the state department of health. This list of those aiding is not complete.

The Connecticut water utilities have, in the past, established a central inventory of pipe and fittings. This inventory was repeated regularly during the war and is definitely a useful tool in times of disaster. The machinery for taking this inventory exists, but it has not been taken within the past year or so. While during periods of localized trouble such an inventory is very helpful, in this particular type of disaster the readily available cooperation of all utilities eliminated the need for use of the central inventory.

RESTORATION OF TREATMENT ON PUBLIC WATER SUPPLIES AND DISINFECTION OF WATER-DISTRIBUTION SYSTEMS

As mentioned previously, it was fortunate that treatment facilities on our public water-supply systems were not appreciably affected, despite the serious effect of the disaster on distribution systems.

At Naugatuck, due to the inability of the hydraulic pumps to handle the chlorinator load subsequent to loss of power for the electrically operated pump, the state department of health furnished a gasoline-operated hypochlorinator on the high service, and this was used for two days until power was restored.

At Waterbury, it was decided to turn the abandoned East Mountain Reservoir supply into the high-service system. Arrangements were made on the afternoon of Sunday, August 21, for the Connecticut representative of a chlorinator company to deliver an emergency chlorinator, which was set up under the supervision of the state department of health, and a flow of about 3 mgd was turned into the badly depleted system Sunday night.

As soon as the water was available under pressure in the distribution systems, the next step was to see that the broken piping systems, restored to service with temporary pipe connections or new, permanent pipe connections, were disinfected and that water of safe bacteriological quality was obtained. The sanitary engineers of the state department of health assisted in disinfection of mains, storage tanks, and standpipes and in arrangements for increasing chlorine dosages.

It soon developed that because of high flows, due to breaks and leaks not all of which had been discovered, together with impaired physical quality, resulting from wash of silt and sediment into streams, the chlorine demand could not always be met by existing chlorinator equipment. The assistance of chlorinator manufacturers was obtained and, where possible, orifices of enlarged capacity were installed, or other changes were made to permit adding greater quantities of chlorine. Supplementing the usual chlorinator operation on water-supply mains, high-test chlorine powder was used in large quantities. In Waterbury and later in other communities, large quantities of high-test chlorine powder were dumped into the gatehouses of the reservoirs, to supplement the chlorine being added in the regular treatment plants.

Free chlorine residuals as high as 6 to 10 ppm were carried at the treatment plants below the reservoirs. In this way, free chlorine residuals between 1 and 2 ppm were carried throughout distribution systems. At Torrington, two trailer chlorinators, one loaned by the Bridgeport Hydraulic Co., were set up to dose large quantities of chlorine into the system.

A lesson learned from the sampling of water-distribution systems, as discussed below, was that those systems in which chlorine was applied in large amounts and high chlorine residuals were secured and maintained, were cleared up promptly, but that where chlorine residuals were stepped up slowly and more cautiously, the clearing-up of the distribution systems took considerable time. The state department of health secured two new chlorine-residual testing discs, with a range of 2.0 to 10.0 ppm, to use with our testing outfits, and these worked satisfactorily. Until they were obtained, the drop-dilution method was used in making tests.

SAMPLING OF SYSTEMS AFTER RESTORATION, AND RELEASE OF BOILING NOTICES

As soon as disinfection was under way, a comprehensive sampling program was established on each affected public supply. Samples were collected for bacteriological examination from a number of taps around each system. There was continuous daily sampling of each supply, until it was released from boiling. In order to save time, samples were collected and delivered to the department laboratories in Hartford, and the laboratory examinations started on the same day, so as to expedite getting out laboratory reports. Samples were inoculated into lactose broth and readings made in 24 and 48 hours. If gas formation was encountered, transplanting was done into brilliant green lactose bile broth, and readings were made in 24 and 48 hours. Negative gas formation in either lactose or brilliant green was required. Five 10-ml tubes were run on each sample.

Results of analyses were tabulated, and after clear samples had been obtained for a period of two days, which were supported by adequate chlorine residuals observed in the field at sampling taps, release of boiling notices was transmitted by telephone to the local directors of health and water utilities.

Because of breaks that occurred, boiling notices were issued in Waterbury, Naugatuck, Ansonia, Seymour, Beacon Falls, Winsted, Torrington, New Hartford, Unionville, Tariffville, New Britain, Rogers, Plainville, Collinsville, Putnam, Thompson, Bristol and Somers.

To aid in the sampling program, which was carried on daily, including week-ends, for two to three weeks after the floods, two dental hygienists of the department were initiated in the technique of water sampling, and they did a good job. The laboratories and the bureau of sanitary engineering offices of the state department of health were kept open on Saturdays, Sundays and the holiday during the emergency period.

In Waterbury, after the distribution system had been fairly well cleared up, the repaired, large low-service main, carrying water from many miles away, was turned on, and this necessitated further sampling and analyses. Also, in Winsted the piping system was promptly flushed and disinfected, but two subsequent breaks in the principal supply line delayed the release from boiling notices.

It is of some interest to note that there was little complaint about chlorine tastes and odors, despite the relatively high chlorine residuals maintained. This again points to the fact that the maintenance of high free-chlorine residuals in distribution systems, such as between 1.0 and 2.0 ppm, may not result in as many complaints as when so-called marginal residuals are maintained.

SPILLWAY CAPACITIES WITH REFERENCE TO UNPRECEDENTED RAINFALL

One result that will almost certainly take place as a result of the unprecedented rainfall is a re-evaluation of spillway capacities. In Connecticut, a special study of dams may be authorized in the present emergency legislative session, and this would undoubtedly include special consideration of water-supply dams. When rainfall as high as 11 in. in less than 16 hours and two-day rainfalls as high as 14 in. must be contemplated for this section of the country, it makes us pause. If an ordinary pond dam goes, there is possible danger to life and property. If a water-supply dam fails, there is added disaster of a depleted public water supply, which may take a long time to replenish. This might be almost a knock-out blow for a community.

A recent book, entitled "Floods", by William G. Hoyt and Walter M. Langbein, makes some interesting references to maximum rainfall; presumably all of these amounts of rainfall recorded must have been very local in character. A reference is made in this book to a rainfall of 7 in. in 30 minutes that fell in Cambridge, Ohio, on July 16, 1914.

ADVANTAGES OF STANDBY POWER

There were some high-service pumping stations, serving portions of distribution systems, that were temporarily put out of operation by failure of electric power. The advantages of standby power are obvious.

In the October flood, electric service failed in the city of Norwalk and the city of Danbury. The rapid sand filtration plant of the First Taxing District of Norwalk and the two rapid sand filtration plants of the city of Danbury employ electric power for operation of chemical feeders, lights, etc. It was a great relief to have standby gasoline-operated generators in both cities, so that the supply of water went on uninterrupted. In neither community was it neecessary to issue boiling notices.

Mention has been made of failure of hydraulic pumps for operation of chlorinators in one or two communities. The Connecticut State Department of Health has not approved the installation of any chlorinating facilities which are wholly dependent on electric power. If hydraulic pumps cannot fill the bill, then gasoline-operated standby is needed, but in that case there should be battery-operated starting equipment and an automatic alarm, operated by a battery or connected to a telephone. Frequent operation of standby gasoline-operated equipment is necessary (one or more times each week), to make sure it will function when needed.

COMMUNICATIONS

One utility has recently advised the writer that, as a result of the flood, his company is now equipping all their cars and trucks with an interconnecting radio system. Experience seems to be that those using such a system wonder how they ever got along without it.

The lack of telephone service in and out of the city is a great handicap. Short-wave radio stations, civil defense communications and state-police communications all are of help and may have to be depended upon, even though they are a poor substitute for the regular telephone.

The dearth of means of communications left much to be desired in the August flood, but by getting responsible sanitary engineers promptly in the field, the state department of health operations went along fairly smoothly. Short-wave radio was used to some extent. The legislature now in session is being asked for funds to set up adequate emergency communications for the state civil defense organization.

LESSONS TO BE LEARNED

Among the important items to be planned for in disaster are:

1. Standby-power provisions for pumping and treatment.
2. Provisions for transporting and distributing water—sources and methods.
3. Use of auxiliary water sources if needed.
4. Knowledge of how to get repair equipment and personnel—other water utilities, contractors and suppliers.
5. Provision of adequate chlorine capacity for high flows following breaks and for high chlorine demands of water which has been subjected to large amounts of surface wash.
6. Knowledge of where to get supplies of liquid chlorine and of high-test chlorine powder, the latter possibly being needed for extra disinfection of restored supplies and of auxiliary water supplies used in emergency.
7. Rapid stepping-up of chlorine residuals for disinfection of piping or tanks, far beyond ordinary needs.
8. Consideration of emergency methods of communication.
9. Special studies of pipe crossings on bridges and in beds of rivers and streams, and development of plans to counteract the effect of washouts.
10. Consideration of types of pipe that will best stand up in locations where heavy washouts, such as along steep slopes, may take away supporting earth under pipelines.

SUMMARY

Despite the serious crippling of numerous public water-supply systems in Connecticut in the 1955 floods, it is gratifying to record the courageous, diligent and successful efforts of all water officials in charge of public water supplies and of their employees, to get the systems back in service in a remarkably short period of time. Several systems in Connecticut were completely or almost entirely out for periods ranging from a day or less to a week or more.

The Federal Government through the Army and the Federal Civil Defense staff teamed with the State Civil Defense staff and was of tremendous assistance in furnishing men and equipment to carry out emergency repairs of damaged systems. Our own State Civil Defense organization was of great aid in furnishing transportation, assisting in various community problems, etc. The U. S. Public Health Service sanitary engineers and sanitarians greatly assisted the state department of health, although more especially working with local sanitarians in areas of sanitation problems other than water supply.

Finally, all of us can look back with pride, as the saying goes, on the extensive repairs and restoration with the knowledge that no water-borne disease came as an aftermath of the disaster. The water-works officials and the state department of health worked as a team to make this possible, with lots of cooperation from all sides, including the public served.

THE CASE FOR A POSITIVE WELL-FIELD MAINTENANCE PROGRAM

BY E. BOYD LIVESAY*

[*Read February 16, 1956.*]

The facts used here to present the case for a positive well-field maintenance program came to light with the renovation of our Jordan Avenue Well Field in 1953. Construction of this well field was started in 1904, immediately after the forming of the Brunswick and Topsham Water District by legislative charter of 1903. Installation was completed and the first water pumped into the mains on January 12, 1906. The engineering work for this well field was done by Freeman C. Coffin, and the construction work by B. F. Smith and Brother, both of Boston. The original well field consisted of 50 driven wells, connected to the pumps by suction header pipe of cast iron, varying in size from 16 in. to 6 in. This number was increased in 1907 to 88 and later, in 1929, three dug wells, 40 ft in diameter and 35 ft deep, were added. Mr. Coffin, in his report of April 29, 1904, estimated that this well field should produce a supply of 1 mgd. It is further noteworthy that B. F. Smith and Brother in their contract for this installation guaranteed a supply of 1 mgd and a pumping rate of 2 mgd for a 5-hour period on a no-water, no-pay basis—the test to establish fulfillment of their contract to be a 30-day pumping test upon completion of the construction.

The original pumping station was a steam powered-plant which was changed over to electric power in the period 1916 to 1918.

In 1907 the first water analysis of this water made by the Department of Health and Welfare was as follows (expressed in parts per million):

Turbidity	0
Sediment	0
Color	2.0
Odor, hot	0

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*Superintendent, Brunswick and Topsham Water District, 9 Town Hall Place, Brunswick, Me.

Odor, cold	0
Free ammonia	0
Albuminoid ammonia	0.012
Chlorine	4.7
Nitrogen: nitrates	0.1
nitrites	0
Oxygen consumed	0.3
Hardness	35.0
Iron	0
Lead	0
Bacteria per cc	4
Colon bacillus	absent

H. D. Evans, Director of the Department of Health and Welfare, in a report several years later had this to say about the quality of the water: "the analysis shows the water to be in its usual first-rate condition; it being entirely free from all evidence of sewage pollution. It is in almost exactly the same condition as when last examined and is very pure drinking water."

Since that time, however, the District has learned to its sorrow that the water from this well field had other qualities not so good. The pH of this water is definitely acid, averaging between 5.8 and 6.3; this, combined with a high CO_2 content, makes the water very corrosive. Down through the years then we have suffered many complaints of "red water" and the resultant iron stains. A part of this "red water" is unquestionably the result of corrosion of the distribution mains, but the author believes he can show that a large part of it originated in the well field itself.

The records of the chemical analyses of this supply from its inception to date are pretty complete. It is particularly interesting to follow the trend of the iron content in this water. From 1908 to 1920 the iron content shows very little variation, ranging from 0.02 ppm in 1908 to a high of 0.2 ppm in 1911. Through the 1920's we find it increasing from 0.2 ppm in 1923 to 0.3 in 1929. In 1934 samples taken at the pumping station showed 0.5 ppm of iron. Through the 1940s, probably because of red-water complaints, these samples were taken from points in the distribution system and show iron contents of as high as 1.4 in 1942. In November, 1953, after our renovation, the iron content at the well field had dropped to 0.23. Samples taken in May and October of 1955 show a "trace" and "negative" reports, respectively.

Records of maintenance work on this well field are not nearly so complete. The few written records show that major maintenance work was done in 1923, when 40 of the wells were pulled and replaced, and again in 1939, when all of the 2½-in. wells were pulled and redriven. Also at this time the suction headers were cleaned, and when we removed a 14-in gate in our cleaning operation in 1953, we found a pulling rod extending right through the gate, apparently left over from a cleaning operation. Regular maintenance work seems to have consisted practically entirely of regularly washing out the sand which had accumulated inside the well points. This work was done in the fall of each year. Apparently no attempt was made to surge any of the wells, nor was use made of any of the several chemicals available for cleaning the well points.

In more recent years there has been a rather sporadic attempt at pumping each well during these fall maintenance programs, with replacement scheduled for those that failed to pump. Unfortunately, for several years prior to 1953 this program seems to have stopped before any wells could be replaced, either because winter weather was setting in, or because of lack of time. In 1953, when we went through this well field and completely renovated it, we discovered that 25% of the 66 well points were completely clogged; 50% were about 75% clogged; and the rest were about 25% clogged.

In 1952 Brunswick suffered a critical shortage of water, due to an extremely dry season, and also to increased demand, occasioned by the reactivation of the Naval Air Station in Brunswick. (The combined population of Brunswick and Topsham increased from 13,600 in 1950 to 18,900 in 1953, an increase of 38.8%.) Something evidently had to be done immediately. The decision was then made to try to increase the yield of the Jordan Avenue Well Field by adding a new well field in this area. The work of driving 76 new 2½-in. wells was started and completed in the fall of 1952. By August, 1953, the suction header joining these wells was completed, and the new well field was ready to be put into operation. It was at this point, in tying the 12-in. suction header of the new well field into the old 12-in. suction header, that we discovered how very badly the old well field needed renovating.

The suction mains were coated with a build-up of rust in the form of a soft, spongy mass, reducing the effective diameter by as much as from 2 to 5½ in. The established operating practice involved starting and stopping the pumps at least once each day. The velocity changes in the header pipes dislodged this coating, with the result that with virtually every start-up rusty or red water was pumped into the mains for a period of up to half an hour. In the course of 25 years' daily pumping, a lot of rust can be transferred from the suction headers to the distribution system.

The entire old suction-header pipe was properly cleaned and cement-lined in place. This work was done by the Centriline Corp. of New York in September and October of 1953. In addition to this, all of the wells were pulled and replaced with new cement-lined, 2½-in. wrought-iron pipe and new Johnson Everdur well-points. The work of replacing these wells was done by the R. E. Chapman Co., who adjusted the well-points up or down to determine the best location for pumping, properly developed the well, and then recorded the amount pumped from each well. The same information was obtained and recorded by the D. L. Maher Co., who installed the 76 wells of the new well field in 1952.

The results of this well-field renovation were readily apparent when we started pumping operations again in February, 1954. In 1950, as a part of a comprehensive engineering survey of our entire system, pumping tests were run on all three pumps at the Jordan Avenue Pumping Station. These pumping tests showed all the pumps to be very inefficient. Number 2 electric pump, the worst, had a pumping capacity of 710 gpm with a discharge pressure of 102 psi and a vacuum lift of 25.3 in., as against a rated discharge of 1,050 gpm. The pump efficiency was calculated to be 47%.

In June of 1953 we were able to pump only 620 gpm from the old well field with this old equipment, the vacuum being 20.3 and the discharge pressure 100 psi. However, in February, 1954, after the old well-field renovation had been completed, we were able to pump 970 gpm, using precisely the same pumping equipment. The vacuum reading was 17.3 and the discharge pressure about 102 psi.

Table 1 contains Pumping Statistics which indicate the trend where well-field efficiency and power consumption are concerned. These data were compiled by computing average daily rates from the monthly totals. While there may be some question as to the validity of individual items shown here, due to variations in opera-

TABLE 1.—PUMPING STATISTICS FOR JORDAN AVENUE WELL FIELD

1 Date	2 Average daily hours pumped	3 Total average daily pumpage	4 Pumping rate	5 Average vacuum	6 Observation well	7 Monthly power consumption	8 Power used per 1,000 gal
	Hours	Gallons	gpm	Inches of mercury	ft	kwh	kwh per 1,000 gal
Dec., 1940	11.15	653,000	975	22.5	13.9	38,200	1.88
Dec., 1941	11.9	560,000	785	22.5	14.8	33,400	1.93
Dec., 1942	10.85	609,000	934	23.0	13.0	37,700	2.00
Apr., 1943	12.8	700,000	910	24.0	12.0	41,200	1.90
1944							
Jan., 1945	19.6	950,000	810	25.5	12.4	65,600	2.23
Jan., 1946	23.6	1,070,000	757	23.5	12.8	70,600	2.12
Dec., 1947	19.0	795,000	698	26.0	13.6	55,100	2.24
Aug., 1948	23.3	798,000	573	26.5	13.2	58,000	2.34
Dec., 1949	16.25	633,000	648	19.7	13.0	43,700	2.23
Jan., 1950	15.51	625,000	670	20.0	11.9	44,000	2.28
Dec., 1951	23.6	818,000	578	25.2	13.2	63,500	2.5
Jan., 1952	23.4	836,000	594	25.3	12.5	63,700	2.46
June, 1953	23.6	875,000	620	20.3	11.5	59,600	2.28
*Dec., 1953	13.4	723,000	904	18.5	11.0	45,600	2.03
[1]Feb., 1954	6.0		970	17.5	11.6		
[2]Dec., 1954	13.55	1,010,000	1,240	15.1	8.7	53,900	1.71
[3]July, 1955	6.83	513,000	1,275	18.5	7.5	20,300	1.25
Aug., 1955	6.61	522,000	1,300	19.5	7.3	20,000	1.26
Oct., 1955	6.05	464,000	1,280	18.0	4.5	18,100	1.26

*At this time part of the Old Well Field had been completed and was being used with the entire New Well Field.

[1] Pumping from the renovated Old Well Field only, using same pumping equipment as for previous years.

[2] Pumping from both Old and New Well Fields with old pumping equipment.

[3] The vacuum gage under the new set-up was raised approximately 8 ft. Therefore, to make vacuum readings comparable, 7.1 should be subtracted from these last 3 vacuum readings.

Note: Present pumps are 125-hp and 1,000-gpm capacity.

tional practice and other factors such as decrease in pump efficiency which have a recognized bearing, the author feels there is no question of the trend established or that this trend can be traced in large part to loss of well-field efficiency.

Column 5, showing average vacuum required, bears this out in particular. In compiling these data, those months have been chosen which had the closest possible water-table levels, so as to make the vacuum from this standpoint relatively constant. However, column 5 shows the vacuum increasing year by year. Similarly, column 8 shows a decrease in power consumption per 1,000 gal pumped. It should be added for purposes of comparison that from 1940 to 1953 the discharge head has varied only from 94 to 99 psi.

In addition to the well-field work of 1952 and 1953, we installed all new pumping equipment in the pumping station in March to May, 1955. Also, in February of 1955 we completed the installation of a completely new and different supply. This explains the sudden drop in daily pumpage at the Jordan Ave. source in 1955.

Summary. The work of renovating this well field, done from September, 1953, to February, 1954, represents the yearly maintenance work of 1941, 1942, etc., which was allowed to accumulate until it had to be done. Had this work been done on a year-by-year basis, the quality of the water could have been maintained at a higher level, and the well-field and pumping efficiencies improved and kept constant, with a corresponding decrease in power costs.

For these reasons we plan to embark on the following annual maintenance program starting this coming fall:

1. Each well will be pumped individually and its present pumping capacity compared to its original recorded capacity.
2. Those that show a loss of efficiency of more than 10% will be surged with that chemical which, by experiment, is found to give best results.
3. Those that still do not respond will be pulled, examined and replaced where necessary.
4. The suction-header will be opened at the several Dresser couplings now in the line, inspected and, if necessary, cleaned.

DETERGENT RESEARCH RELATED TO WATER AND SEWAGE TREATMENT†

BY F. J. COUGHLIN*

[Received Feb. 24, 1956.]

This is the first report on the research activities sponsored by the Association of American Soap & Glycerine Producers, related to questions which are raised about detergents in some water supply and sewage treatment situations. The report will be of special interest to the members of the Association who manufacture detergents and detergent raw materials. The Association's research activities have been handled by several technical committees under the guidance of the Technical Advisory Committee, with L. H. Flett of the National Aniline Division, Allied Chemical & Dye Corp. as Chairman. It is well-nigh impossible to do justice to the efforts of the individuals and companies participating in this work and to the spirit of cooperation which has been shown.

QUESTIONS RAISED

Requirements for water are constantly increasing, both for household and industrial use. Consideration of the problem of adequate future water supplies raises questions about the proper disposal of all types of waste, including domestic sewage. One approach to the waste disposal problem is through the research and other programs which are being set up by industry and by Federal, State, and local agencies. Our industry is proud to take a part in this broad program.

For some time now water supply and sewage treatment people have shown interest in detergents. This interest seems to lie in the possible effects, if any, of the normal use of detergents on water supplies and in sewage treatment plants. Detergents are sometimes associated with problems of frothing, sedimentation, and coagulation difficulties in water treatment plants. In the treatment and disposal of domestic sewage, the normal use of detergents is said, in some instances, to cause frothing and to retard the biological processes of decomposition. The Association's research program undertakes to determine whether there is any connection between the difficulties reported and the normal use of detergents and, if so, to what extent. These problems had existed before the advent of detergents and it would be expected that they would increase in severity as the population increases.

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†An abbreviation of a report read at the annual meeting of the Association of American Soap & Glycerine Producers, Inc., New York, N. Y., Jan. 27, 1956, by the Chairman of the Technical Advisory Sub-Committee on Research.

*The Procter & Gamble Co., Miami Valley Laboratories, P.O. Box 175, Cincinnati 31, O.

The interest of our industry in cooperating in the solution of water supply and waste water disposal problems goes back a good many years, and our Association and industry want to play our part in attempting to determine the facts and ease the problem. The industry is glad to have a common interest in these problems with many able and conscientious groups, including the sewage and water treatment operators, the sanitary engineers and chemists involved in water supply and waste water disposal, the Federation of Sewage & Industrial Wastes Association, the American Water Works Association, the U. S. Public Health Service, and the Ohio River Valley Water Sanitation Commission, known for short as Orsanco.

Some of the people interested say that detergents are causing no difficulty. Going to the other extreme, the opinion is also expressed that detergents are causing difficulties now and are likely to cause further difficulties in the future. The most frequently expressed opinion seems to be that the information available does not give cause for major concern and that steps should be taken to obtain additional facts to answer the questions raised. This appears to be the thinking of U.S.P.H.S. and Orsanco and expresses the attitude of the Soap Association Technical Committee.

Until the time when satisfactory answers to all these questions are available, our industry will wish to take sound constructive action and cooperate with others as a matter of broad public responsibility in seeking the possible solutions to these difficult problems.

DEFINITIONS AND TECHNICAL INFORMATION REGARDING DETERGENTS

By way of definition, the term "detergent" is used in this discussion to refer to the complete product as it is found in the package on the grocery shelf or in barrels or drums for general bulk industrial uses. In homes, detergents have grown to where their sales are well over half the total of all washing products. Detergents contain surface active agents, sometimes referred to as "surfactants", and in addition they may contain inorganic and organic builders. Of the surface active agents, alkyl benzene sulfonate, a derivative of petroleum, often referred to as ABS, is used more extensively than any other. The most important builders used are the complex phosphates.

For those interested in further information on the characteristics and behavior of detergents, papers by Haney (1), Gowdy (2), and Hoyt and Flett (3) are recommended as they pertain to water and sewage treatment questions. The significance of the quantitative aspects of the behavior of detergents is not always recognized. At extremely low concentrations, detergents do not possess the same characteristics—such as foaming ability or emulsifying properties—which they show at the higher concentrations suitable for cleaning purposes.

To obtain the kind of suds that the housewife likes in her dishpan, she may use about 3,000 parts per million or three-tenths of one per cent of the packaged synthetic detergents. This would be equivalent to about 600 ppm or six-hundredths of one per cent of surfactant.

Typical concentrations of detergent likely to be present in domestic sewage have been reported by Haney with 53 ppm as the highest value (1). This would be equivalent to 10 to 15 ppm of surface active agent, assuming, for the purposes of obtaining a maximum figure, no decomposition or die-away. The concentration of surface active agent present in surface waters would therefore be considerably lower because of dilution effects, and in some instances might be zero. Some of the difficulties in water treatment have been attributed to as little as 1 to 4 ppm of detergent.

Now to give you an idea of just how small one part per million is, one pound in five hundred tons is one part per million—or one 1¼-pound package of household detergent in 150,000 gallons of water is one part per million. It is remarkable that methods can be developed to find such trace quantities.

One manifestation of the technical interest in this problem has been the development of a certain amount of literature which associates detergents with the difficulties encountered. Examined critically in the light of the chemistry and behavior of detergents, it is apparent that proof has not been established that detergents necessarily create any ill effects. Also, it is quite evident that other factors might have caused the adverse effects which have been reported and, further, it could very well turn out, when all the facts are in, that detergents do not produce the difficulties for which they are blamed.

Biological Degradation

The frothing experiences in sewage works led to some apprehension and speculation to the effect that some of the detergent components, particularly ABS, might be stable enough to resist decomposition and breakdown in sewage treatment and might pass on unchanged into surface waters, such as rivers and lakes. These apprehensions arose even though lack of sound analytical procedures made it impossible to obtain reliable objective measurements. Thus, there was no real proof that such things were happening.

The California Research Corp. saw the importance of developing fundamental information on the fate of ABS in sewage treatment processes and undertook a practical scale study. An unequivocal method of analysis was used, employing ABS tagged with radioactive sulfur. This work, reported by House and Fries at the New York Sewage and Industrial Waste Association meeting in New York City on January 19, 1956, shows that in the activated sludge plant in which the tests were made, 80 to 90% of the ABS was destroyed by the normal sewage treatment process.* This is the same efficiency as obtained on normal sewage in this plant.

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*Sewage & Industrial Wastes, Vol. 28, No. 4, Apr., 1956, pp. 492-506.

ANALYSIS OF ABS

In view of the fact that methods of analysis for the extremely low concentrations of ABS or other surfactants in water and sewage were inadequate, it was soon apparent that an analytical method which would give reliable results was needed in order to determine the extent of the problem.

A method known as the Methylene Blue procedure has been used rather generally in the past and it is only recently that its weaknesses are coming to be recognized. Unfortunately, many people have relied on the Methylene Blue method and quite a bit of literature is based on it. It is far from satisfactory, because urine, tea, coffee, and distilled water extracts of such materials as straw, leaves, and rotted wood—all of which contain natural surfactants—appear by this method to contain ABS when, in fact, it is not there. The A.W.W.A. Task Force Report(1) points out that the natural production of surface active agents is considerable and that raw waters may be expected to contain a variety of natural surfactants.

Of course, the Methylene Blue method is still suitable where a quantitative result is not essential and when the concentration of ABS is obviously so low that it is insignificant. For example, using this method which may give fictitiously high values, the Ohio River at Anderson Ferry, Ohio, has been ranging from about 0.02 ppm to 0.56 ppm, based on three samples per week over the past year. Even if the entire amount of "apparent ABS" were real, there is no need for checking the Ohio River by more laborious and time-consuming methods.

To develop a suitable method of analysis which is unaffected by interfering substances is the mission of the Soap Association's Sub-Committee on the Analysis of ABS. Such a method will not only make it possible to deal with the problem in a quantitative way but will be a basic tool for further research.

In giving top priority to the analytical problem, the Soap Association Technical Committee is following the suggestions of the Ohio River Valley Water Sanitation Commission and the American Water Works Association Task Group on Detergents.

As a matter of fact, the Ohio River Valley Water Sanitation Commission's interest in the possible effects of detergents stimulated the formation of the present Soap Association Sub-Committee on the Analysis of ABS. Orsanço set up a Detergent Sub-Committee as part of the Chemical Industry Advisory Committee. This Sub-Committee, in turn, invited companies engaged in the manufacture of detergents and detergent raw materials to cooperate in the development of a valid analytical method. The U. S. Public Health Service at the Taft Engineering Center in Cincinnati also was invited to join in the project. For a while this group proceeded on an informal basis. Later on, since all the industry members of the informal group were members of the Soap Association, it was a natural move for them to become an official committee sponsored by our Association. The Soap Association committee has had five meetings in the past two years and it is estimated that the ten committee members have spent over 17,500 man hours on laboratory tests and experiments. The new analytical method should be considered a noteworthy accomplishment.

To make a long and highly technical story as short and as non-technical as possible, the new method involves the measurement of the amount of ABS in the sample in question, first by removal of the ABS by adsorption on activated carbon. This begins to sort out the ABS from the larger amounts of other organic matter present. Then the ABS is removed from the carbon column, and next a further sorting out by chemical methods is accomplished. When a sufficiently large quantity of pure ABS has been quantitatively obtained from the sample, the final step is to measure it qualitatively and quantitatively by the use of an infra-red spectrophotometer. This new method, checked out carefully by the committee, should soon be ready for publication.

The Soap Association technical group is the first to recognize that the method as it has been evolved will not be practical for the average sewage works or water treatment operator to use routinely. A simpler method for making routine analyses is still needed and we hope to come up with something on this, too. The Taft Sanitary Engineering Center of the U. S. Public Health Service has reported on a new colorimetric short procedure called the "Methyl Green" method. The Monsanto Laboratories have also been doing some extracurricular work and are about ready to report on another short method. The study of shorter methods will continue to be an important part of our future program.

WATER TREATMENT

In the water treatment area, the need for a more active program became apparent when the quiet on the waterfront was disturbed at Wheeling, W. Va., around Thanksgiving of 1953. Large quantities of froth formed on the Ohio River and in the water treatment plant there. The froth was accompanied by bad taste, discoloration, and extreme difficulty with filtering and settling. The river had been at an extremely low stage and almost in pool. This low flow brought about the presence of high concentrations of various organic and inorganic substances in the river water. When frothing occurred, the river water appeared to contain about 1 ppm of "apparent ABS", using the Methylene Blue procedure, which includes the amounts of any interfering substances present.

With such a low level of ABS in the water, it was extremely difficult for anyone to postulate how detergents might have produced the foam. On the other hand, the foam contained a high concentration of ABS, which was present chiefly on finely divided solids held and suspended in the foam. This, while difficult to explain, was still not conclusive. Since that time, incoming water with the same concentration of ABS by the Methylene Blue method has been treated by the water works at Wheeling without any trouble. In retrospect, a fair and reasonable point of view seems to be that detergents from domestic sewage were not the principal cause of the Wheeling froth, if indeed they had any appreciable effect at all.

PHOSPHATES

More recently, in instances where water treatment plants have encountered difficulties with coagulation and sedimentation, there has been some speculation that the complex phosphates from household detergents might be involved.

It is true that if enough complex phosphates are present, they could retard coagulation and sedimentation in water treatment. In fact, it is because of this particular property, that these materials have become such an important constituent of household detergents.

However, before the conclusion is reached that they cause such troubles, there should be an answer to the question: "Are the complex phosphates or other phosphates present in sufficient concentration in the surface waters going into the water treatment plants in question to produce the effects reported?"

It is difficult to measure the possible effects of the complex phosphates from the household use of detergents on water treatment processes. The reason is that the complex phosphates undergo changes during the washing process itself, during their travel through the sewers, and in the sewage works. Furthermore, any residue which passes on to surface waters is expected to undergo further changes, because the phosphates are susceptible to being decomposed by the plant and animal systems present in all surface waters.

There are many other unanswered questions. For example, "What are the conversion products, if any, which reach the water treatment plants?" "How quickly do the complex phosphates revert to the simpler forms, and what effect, if any, is produced by the conversion products?" "If the phosphates have any effects, how much of the effect is contributed by the phosphates from household detergents, how much by the naturally occurring organic and inorganic phosphates, how much by the phosphates from fertilizers, how much by phosphates from industrial plants, and how much from any other source?"

A Phosphate Committee was recently organized in our Association to explore questions which have been raised. This hard-working committee includes our own members and, in addition, non-member organizations in the phosphate industry who are interested in participating. The committee has started out on the problem of establishing good methods of analysis for the types of phosphates in the low concentrations which might be found in water and sewage. H. V. Moss of Monsanto Chemical Co., who is an active member of several other committees in this general field, is the able and efficient Chairman of the Phosphate Committee.

Kansas

Our technical groups have already had a few opportunities to help others to investigate some of these difficult problems. After a succession of several drought years in Kansas, serious water quality problems have been encountered in various parts of the state, and there is speculation that detergents are a factor in causing the difficulties. In fact, last year a bill was introduced in the Kansas legislature which in essence would have made it unlawful to put detergents into a public sewer. Working on the principle that legislation would not solve the problem, but that research would, our Association offered its help. A representation from our Technical Advisory Sub-Committee on Research and our Committee on Analysis discussed our activities in detail with people from the Kansas State Board of Health, and a report was made at the April, 1955, joint meeting of the Kansas Sewage & Industrial Wastes Association and the Kansas Section of the American Water Works Association (4). A few weeks ago, the Kansas State Board of Health people asked us to cooperate further in studying current problems and the Technical Committees have been glad to take steps to assist in the present situation.

Britain

A British Government Committee on Synthetic Detergents is at present studying the question there. The Association's activities have been reported by members of the Technical Committees to their associated companies in Britain, and in this manner the information which our Technical Committees have developed has been made available to the British Committee. It is hoped that the work which is under way in the United States may be generally applicable to the British situation and may be helpful in solving the sewage treatment problems and any water quality problems which exist over there.

OHIO RIVER VALLEY SANITATION COMMISSION, DETERGENT SUB-COMMITTEE

To a great extent, because of the Wheeling experience right in its own bailiwick, the Ohio River Valley Water Sanitation Commission appointed its Detergent Sub-Committee, mentioned previously. Prior to this, E. J. Cleary, Executive Director and Chief Engineer of Orsanco, had suggested a program of investigation that the Sub-Committee might consider. It is indicative of Cleary's foresight that after these suggestions were reviewed carefully by those interested in the problem, it is essentially the program which is being followed at the present time. Soon after its appointment, the Orsanco Detergent Sub-Committee extended an invitation to the Soap Association to help in the investigation of this broad industry question, since it extended beyond the confines of the Ohio Valley. The Soap Association was ready and willing to cooperate and accepted the invitation. It was a natural development for the Association to take over the analytical problem as has been described and to organize and underwrite further constructive research investigations.

RESEARCH PROJECTS

The Technical Advisory Sub-Committee on Research was asked to recommend the problems for study, where they should be placed, and to determine the budget required to finance the work. The Association then solicited and obtained the funds required from member and interested non-member companies.

The question as to the type of ABS to use for study was resolved by making a composite of the alkyl benzene from the four suppliers on the Sub-Committee on Research. From this composite, Wearn and Ross of Colgate-Palmolive Co. have produced a composite ABS for use in the Association studies.

A system was set up where liaison with each of the projects is being handled by one or more members of the research committee, and each of the projects has been visited by members of the committee at least once this year.

The first project to be placed by our Sub-Committee on Research was at M.I.T. The Continental Oil Co. people had been discussing with M.I.T. the detergent problem from the point of view of possible biochemical degradation of the surface active agents. It is obvious that breakdown of the surface active agent to the point where surface activity is destroyed would probably remove it as a cause of the frothing in sewage works, and would completely eliminate the problems in water treatment associated with the surface active agents present in detergents. The work is under the direct supervision of Prof. Ross E. McKinney in the Civil Engineering Department. Professors Clair N. Sawyer and Rolf Eliassen are also associated with the project.

The second project was placed at the Sanitary Engineering Research Laboratory of the University of California at Berkeley, under Professors E. S. Crosby and P. H. McGauhey. They are following up on the work of the California Research Corp., mentioned previously, and are making a more comprehensive study, under a wider range of conditions, of the fate of ABS in sewage treatment and in surface water supplies.

The University of Wisconsin project is in charge of Prof. G. A. Rohlich and L. B. Polkowski. They are working on the causes and prevention of frothing in sewage treatment plants. Frothing systems free of detergents will be studied, as well as those containing detergents. As the headlines usually associate detergents and frothing, the Association obviously has a vital interest in getting to the bottom of this problem.

The fourth project is under the supervision of Professors J. C. Dietz and R. S. Engelbrecht at the University of Illinois. It will study, as a first phase, the complex phosphate components of detergents, and later ABS, in water treatment plants. To get at the question of possible amounts that may be present in surface waters, it will survey the type and amounts of phosphates present in some of the waters in the State of Illinois, using the analytical tools supplied by the Phosphate Committee. Also, it has set up a pilot plant unit to study the settling operation in water treatment.

In the judgment of the technical group, our research projects have been placed in excellent hands and cover the difficult areas of water and sewage about as effectively as any four projects could. These explorations, when completed, should reveal new and valuable information.

SUMMARY

Your Technical Committees hope that this report gives you a clear picture of the background and purposes of the research which the Association is sponsoring in the water supply and sewage treatment areas.

The technical group hopes that you have an impression of the considerable amount of effort that is going into the study of the problem by representatives from the member companies. This report should convey to you the picture that this is a completely non-competitive activity in which the cooperation of the interested people and companies is excellent.

This report cannot have missed conveying to you that there are a number of interpretations of the facts which are available. If in this situation the industry had chosen to remain aloof, it is almost certain that the unproved and unfair interpretation that detergents are to blame for the numerous difficulties reported to have been accepted by default.

The technical group hopes that those who do not agree with our evaluation of the situation will accept the comments in this report impersonally and constructively, as they are intended.

The Technical Committees urge all those interested in this problem to take an objective and scientific point of view, to investigate further if there is any reasonable doubt, to accept as facts only such material as is properly documented, and to limit conclusions to the data and facts available.

Your Technical Committees appreciate the demonstrated interest of the Association management people and the cooperating non-member companies who have already appropriated $128,000 to carry the program along for a couple of years.

In conclusion, your Technical Committees hope that you and others are convinced by the information in this report that it could very well develop that detergents have not been responsible for all the things blamed on them. Your Technical Committees are interested in working with others in this field and are looking forward in the next couple of years to finding the answers to at least a few of the difficult questions before us. They hope that the information acquired will represent a real contribution to the technology of water supply and waste water disposal. Your Technical Committees recognize that the water supply and sewage treatment areas are of great importance to the public and they want to assure the people in these fields of the Association's active and continued cooperation.

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ELEMENTS OF AN EMERGENCY WATER SYSTEM FOR FIRE SERVICE

BY JOHN C. ADAMS, JR.*

[Read March 15, 1956.]

It is predicted that in the event of a bombing attack, the municipal water system will be either entirely inoperative or so damaged as to be useless for fire-fighting purposes. The pressure waves resulting from an atomic explosion will cause vertical displacement of building walls, resulting in a failure of water-service pipes which pass through them. It would not take too many such failures to reduce substantially the pressure in the system, so that it would be impossible to supply fire hydrants properly. Even with skilled employees, fully familiar with the distribution system, it would take many hours to isolate breaks and make even a portion of the system operative. Some method of providing a supply of water to fire fighters which is independent of the usual municipal system must be developed. It is my purpose to point out some of the elements of such an emergency system.

It should be stated at the outset that the solution for one city or town is not directly applicable to another. What will work for Boston will *not* necessarily work for Springfield. This matter of an emergency water-supply system for fire services has already been carefully considered for five specific cities in Massachusetts. The recommendations for each of these cities, while not the same, are based on certain fundamental elements. Preliminary studies resulted in the following conclusions:

1. Fire fighting will not be possible except at considerable distance from ground zero. Many small fires of the secondary type will occur over wide areas. Secondary fires are those which are indirectly ignited by the bombing, such as those caused by overturning space heaters, cracked gas pipes, disrupted electrical service, or similar causes. Heat radiation will also cause fires at some distance from ground zero. It may also be possible to fight or at least contain some of these.

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2. Single fires of conflagration or fire-storm magnitude may occur which can be fought only from their outer edges or perimeters.

3. Areas where fires cannot be controlled with the water available will have to be abandoned and efforts made to prevent the spread of the fire to adjacent areas.

4. It will be impracticable to supply the large fire-flow demands normally used in peacetime for all of the fires that may occur.

5. Many parts of the existing municipal water systems will be inoperative and water must be obtained elsewhere; from harbors, rivers, lakes, and ponds.

6. Many cisterns or tanks must be provided throughout the municipality, from which to draw water for direct fire fighting.

7. Tanks must be kept full at all times and provisions made for replenishing them during the fire by means of a system of relays through other reservoirs.

8. For relaying the water from the primary sources, fireboats, land-based mobile pumpers and large quantities of lightweight pipe and hose must be provided and kept at convenient locations, where they can be readily moved into or near the area on fire.

9. Any system of emergency water supply must be independent of existing local systems and entirely mobile, and a definite plan must be prepared in advance for its use when needed. Specially trained crews will be required to set up and operate the auxiliary water systems following an attack.

Demand Rate

Naturally, the design of any water system for domestic or fire service, whether permanent or auxiliary, is dependent upon the quantity of water which the system must convey. Early study of the fire-demand rates which would be required following an atomic attack led to a quick but firm conclusion that fire demands as we know them for isolated peacetime fires were out of the question. Water for fire-fighting purposes will be an extremely scarce commodity, and what water is available must be put to the most efficient use. As there will be so many fires following an attack, the fire-fighters must either fight only those isolated fires which can be extinguished with a small quantity of water, or use the available water to prevent the spreading of large-area fires.

For one city which was studied, the maximum design demand rate was selected as 1.25 gal per minute per 1,000 sq ft of building floor area. While this seems like a pitifully small quantity, it should be realized that this design demand rate was applied to the entire city, block by block. Presumably, there would be only enough manpower to fight fires in a small percentage of the total number of blocks in the city. Therefore, water provided at the design rates for blocks at which fire fighting is not being undertaken will be available for application to those blocks at which the fire fighters are active.

Storage Tanks

Once the design demand rate has been established, a means of supplying the rate must be developed. On the concept that it will take time for the auxiliary water-supply system to be set up and supply lines, pumps, and other necessary apparatus to be activated, it is necessary that local storage be made available for initial fire-fighting purposes. Local storage should consist of ground or low-head reservoirs, located adjacent to the blocks they serve and within 500 to 750 ft, where possible. They should also be located within 750 to 1,000 ft of one another, so that the water can be relayed from those not in use to those which are being used.

The capacity of these storage tanks is simply the demand rate that they serve multiplied by the interval between the time in which fire fighting is begun and the time when the auxiliary supply system can be brought into service to replenish the tanks. This time interval may vary from city to city, or even from area to area within cities, dependent upon the overall relay length from a source and numerous other factors. It is admittedly a judgment factor. At Olney, Md., the Federal Civil Defense Agency has conducted numerous practice exercises, using quick-coupling pipe, pumpers, and other equipment. Presumably, information is available regarding the amount of time required to lay and place relay piping in service. In most of the areas studied in the Massachusetts cities referred to above, the storage time was chosen as one hour. It is important to note that this is one hour following commencement of fire-fighting operations and not one hour following an attack. Further, it should be noted that since storage would be provided for a one-hour period for the entire demand and due to the aforementioned manpower limitation and the fact that all blocks would not be fought simultaneously, additional nearby reservoirs not being used can be made available to extend the one-hour period for those reservoirs being used.

Having established a demand rate and selected and sized local reservoir capacities, the next and most difficult problem is to plan methods of replenishing the storage reservoirs after the initial reserve has been used. The word "plan" is important, because a scheme must be evolved which is simple, fast, and sufficiently flexible so that variations may readily be made, due to circumstances such as accumulated rubble or other difficulties which would not be known until after the actual attack.

Sources of Water

Sources of water would be rivers, harbors, lakes, and possibly large storm conduits in some instances. Possible intake locations should be carefully studied in advance and any necessary preliminary construction for easy access made. Where land-based pumpers are to be used at a natural body of water, and particularly at tidewater, a dock or ramp may be necessary to locate pumps within the range of their allowable suction lifts. In some locations on tidewater, special self-propelled fireboats might be used. Some preliminary work has been done on the idea of converting the Navy's 36-foot L.C.V.P. boats for such service.

Where the bank of a pond has a very flat slope, a special sump with an intake channel has been developed. Some consideration has been given to the use of turbine pumps, suspended from bridges.

In the final analysis, the selection of the type and location of intake is dependent upon the particular local conditions and upon the relay system through which the pumps will replenish the storage tanks with water.

Relaying of Water

In the problem of relaying of water there is perhaps the most disagreement amongst those who have studied these problems. Some contend that pipes should be laid on the ground ahead of time, and only the necessary repair work done after the attack. Others claim that the conditions after the attack will dictate the route and type of distribution piping that will be necessary, and thus all piping should be laid after the attack.

In either event, a type of lightweight, quick-coupling pipe has been developed which can be laid by a trained crew. This pipe is made of lightweight steel or aluminum. During World War II, the British used a great deal of quick-coupling pipe very effectively in fire-fighting operations following incendiary attacks. The Federal Civil Defense Agency has purchased a supply of this pipe, including fittings and valves, and has allotted supplies to the various cities designated as prime targets.

In some cases, relays will involve such large distances that booster series pumping will be necessary. The need for booster pumping is purely a hydraulic problem, dependent upon the quantity of water being pumped and the length and size of pipe.

Summary

In a very few moments, I have tried to mention a few of the basic elements that should comprise an emergency water-supply system for fire service. My purpose has been solely to arouse your interest in this subject, which I frankly believe has not been given sufficient attention. Our present water-supply systems are highly vulnerable to peacetime failure, let alone a bombing attack. I believe that it is the minimum duty of each water-works superintendent and fire chief to find out what equipment, such as pipe, fittings, valves, and pumpers, is available to him from Federal or State Defense agencies and to make a study of his city or town, so that, if such an emergency arises, he will at least have a prepared plan on how to place such a system into service.

I also believe that superintendents and fire chiefs should see this equipment, learn how to operate it and then instruct their various crews in its operation.

You owe it to the communities you serve to learn all you can about this problem. There are various publications on this very important matter available from the Federal Civil Defense Agency, the National Fire Protection Association, and other agencies. Here in Massachusetts, the State Civil Defense Agency has had printed, for the use of such persons as yourselves, the reports on the five Massachusetts cities studied.*

How many of you here today know how you would go about providing an emergency water-supply system for fire service, if faced with a complete failure of your present system?

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*Studies and Reports by Coffin & Richardson, Inc.

CIVIL DEFENSE IN MASSACHUSETTS

BY JOHN J. MAGINNIS*

[*Read March 15, 1956.*]

Civil Defense came into permanent being in 1950, through the enactment of Federal Public Law 920, and in Massachusetts by the enactment of Chapter 639, Acts of 1950.

The State and its political sub-divisions have been made *primarily* responsible for the operation of Civil Defense, and many of our present problems arise from this situation. In the light of present-day conditions, it is now a quite widely accepted belief of those who are close to the Civil Defense problem that the intergovernmental responsibilities for Civil Defense are presently inappropriately defined and assigned. The view now held is that the states have a responsibility which, by the realities of the problem, they cannot effectively discharge. They have no significant degree of real policy formulation and technical leadership. The consequence is that they have been unwilling to bear the heavy financial burden involved.

There is much evidence that changes in the concept of Federal Civil Defense, with regard to its relation to the states and subdivisions, are imminent. During this session of Congress, the Military Operations Subcommittee is actively investigating this problem. This Committee (Holifield Committee) has indicated that its hearings will be exhaustive, that it will probe all phases of the subject, and that it will submit legislation to the Congress which will provide for the establishment of an effective Civil Defense in the nation.

Let us now look at the situation that faces us in Massachusetts. I think there can be no question in anyone's mind but that war is a real possibility. Certainly the aims with their resulting actions of the Soviet Union, since World War II, have made this evident. We know that the Soviet Union has the capability of striking any target in the United States. We know that they have the planes, and we know that they have the weapons—and by weapons, I mean nuclear weapons in the megaton range. We also know as the months go by they are in a better and better position to carry out such a mission. We know, too, that Massachusetts is vulnerable because of its geographical location and concentration of important industrial and military installations. So the threat is there, and we are trying to prepare ourselves against it. We also know that war will be all-out, and that what we have to meet the initial onslaught with, when it comes, may pretty well determine the degree of success that we shall have in overcoming it.

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Should a sudden attack occur, we do not have a firm idea as to how much warning time we shall have before the bombs actually fall, and the probability is that we shall never have a guaranteed time. From all information that has been made available to us, it appears at this time that we can count on about two hours of warning time. While the establishment of early warning lines and other radar defenses, that we now have, do give greater insurance against surprise attack, it has not increased our warning time greatly, for much of this advantage is being cancelled out by the increased speed of new planes. With conventional planes we might well expect four to six hours of warning time, but with Soviet jet bombers coming into the picture more and more every month—bombers like our new B-52s—it is doubtful that we should have more than two hours of warning time from the time that these planes were first detected until they were over our cities in Massachusetts. All our planning assumptions are based on this figure.

In Massachusetts we have three critical target areas, as designated by the Federal Civil Defense Administration. These cities are Boston, Worcester and Springfield. I should like to point out also that we have a small section of the State which lies close to Providence, R. I., and which is included in the Providence target area. Also, although the actual target area of Hartford, Conn., does not impinge on the Springfield area, the close proximity of these two cities does give rise to some problems. So we have a situation of three fairly sizeable urban areas that are relatively close together, and two others close to the state line. We have about 5,000,000 people in Massachusetts, and about 3,000,000 of them live in these critical target areas. Therefore, we are faced with the problem of doing something about approximately three-fifths of our population.

In the past, Civil Defense has been almost entirely a post-attack organization. By that I mean that Civil Defense has been organized to go into action after the disaster. In other words, it was a sort of "pick-up-the-pieces" organization. It is evident from the facts now facing us that, unless something is done before the disaster takes place, there are not going to be too many pieces to pick up. Today we are thinking of Civil Defense in terms of a pre-disaster organization, as well as a post-disaster organization. It is a far greater operation all around, for it means that the better job we do in saving people from injury and death, the bigger job we shall have to do after the attack is over in taking care of them. It has, therefore, become an undertaking that requires a vastly expanded organization and operation, and has, in fact, become a highly important part of our total defense organization.

How are we, then, to meet this threat? How must the Commonwealth of Massachusetts organize itself, and how must its Civil Defense be set up in order for us to be prepared for a war-borne disaster?

Civil Defense organizations in the various states are placed in different positions in the state organization. Some are in the Military Department under the Adjutant General; some are in the Department of Public Safety; some are in a separate agency under the control of a commission, and some are a separate agency directly under the governor. In Massachusetts, the Civil Defense Agency is in the Executive Branch, responsible directly to the Governor.

The first job that was undertaken by me, when I came in two years ago as Massachusetts Civil Defense Director, was to institute a reorganization of the Agency on the basis of new requirements, brought about by the increased size and deliverability of nuclear weapons, and the corresponding threat to our population. The organization had to be brought into line with the realities of our present situation. This was accomplished by setting up the organization with which we are now operating, as shown on our Organization Chart.

We are organized somewhat along the military pattern with a staff and with services. We have, under the Director, a Deputy Director, 6 staff positions, 17 service positions and 22 field positions—a total of 47 positions in all.

So much for organization—let us look now at how we operate. We are fortunate in Massachusetts to have Civil Defense set up in the State organization in the way that it is. I referred earlier to the fact that the Director is responsible directly to the Governor, with no intervening authority or department head. He is directly under the Chief of State and has direct responsibility to him. The Civil Defense Agency is a coordinating agency of public and private resources and, because of its position of independence under the Governor, it is an ideal position to accomplish such coordination. Compliance among state agencies has been accomplished through the issuance of appropriate orders by the Governor. We had a practical application of how Civil Defense works in the State during the August, 1955, floods, by the issuance of a proclamation by the Governor, declaring a state of emergency and directing the Director to "take all steps and do all such things as I personally might do if present by virtue of Chapter 639 (Civil Defense Act) to combat such emergency and the effects thereof." This placed the Director in complete and unquestioned control of the State and municipal machinery during the period of the emergency and placed the responsibility for dealing with it squarely on his shoulders.

Our operations fall into several areas of activity. First of all, there are our out-of-state activities. These have to do with the Federal Government or national organizations and are handled primarily through the Federal Civil Defense Administration. Beside this, we have direct operational contacts with other states through formal mutual-aid compacts. Massachusetts has 20 mutual-aid compacts with other states. These compacts, in my estimation, have no great value, for they appear to be operationally unsound, especially under present circumstances. In Region I, during the national exercises which take place annually in June, by common consent, all states in the Region agreed to make requests for, or offers of, assistance from other states through the Regional Office, rather than going directly to other states. It simply means that in a disaster of great consequence, say one affecting many states, there must be a clearinghouse for requests for, or dispersals of, resources from national or other states sources to an individual state.

The second area in which we operate is within the State organization itself. Ours is the responsibility to coordinate the organizing of the State and all its departments and agencies to meet any disaster. We must evaluate and define the full resources of the State, in order to utilize them for an emergency. Civil Defense is not the sole job of the Civil Defense Agency; each department of the state has the inherent responsibility for its organization for Civil Defense purposes. The Massachusetts Civil Defense Agency has, of course, the responsibility for supervising and coordinating such activities. In brief, an agency has departmental responsibilities, such as the protection of its own resources; the determination of essential functions and resources—that is, those that must go on regardless of what the emergency is; the determination of resources available to Civil Defense; establishment of alternate headquarters, and emergency succession of its officials. It also has service responsibilities, such as the assignment of personnel to Civil Defense staffs; organization and training of available resources for Civil Defense functions, and for the actual performance of assigned Civil Defense functions in time of disaster.

We are now in the process of evaluating our State resources. Every agency in the state now has a Civil Defense Officer, who has assigned duties in this respect. Before too long we shall be in a position to know pretty much what State resources we are going to be able to call upon in a great emergency. These different agencies of the State are now in the process of determining where alternate headquarters are going to be; what records they must duplicate; where they are going to store dispersed material. I am particularly pleased with the way this phase of the work has developed in our state.

Probably our most important area of activity is with the subdivisions of the state—the 14 counties and 351 cities and towns. As indicated earlier, we have set up our field organization, in order to be able to discharge our duties to the local organizations more effectively. Through our Areas and Sectors we are able to give the local directors more individual attention and support than formerly. This organization is already beginning to prove itself. You must realize that a great majority of these communities have volunteer Civil Defense directors, who carry on these activities in addition to their regular daily work. They cannot, therefore, be informed on all the things which they should know about their Civil Defense duties. The help and assistance which the Sector Directors are able to give them has already raised the morale and efficiency of many local organizations. Best of all, it gives us a direct contact with and, in an emergency, control over local Civil Defense. We have a clean and direct command channel for operations.

And finally we have another general area of activity, and that is with the public at large. This field has to do principally with public information and public relations. It has to do with the dissemination of information of a Civil Defense nature to the general public. It is at once one of our most important activities and one of our most difficult. Lack of public interest is constantly being talked about as a large factor in the ineffectiveness of Civil Defense as a whole. Certainly some of this springs from the uncertain program that Civil Defense has offered in the past. I believe, however, that the threat is now great enough and our program to meet it well defined enough, for the so-called public apathy to be effectively attacked and, I hope, dissipated.

To carry on these operations we have been very badly handicapped insofar as headquarters are concerned. The Legislature has appropriated, and plans are now going forward, for the building of an underground structure, to house both administration and control center, that will cost approximately $1,500,000. None like it now exist in Civil Defense, and when it is completed it should be the finest in the country. We now make it a hard and fast rule that administration and control centers of State, Area and Sector must be in the same location.

Now let us look at our problem. As I have stated earlier, we find ourselves in Massachusetts in the following situation: 5,000,000 people; three critical target areas; 3,000,000 people in these target cities; two hours of warning time—a pretty grim situation. The destructive power of megaton weapons is so devastating that there is no serious thought being given to a program of shelter construction. If we want to save our people, we have one choice and one choice only—that's to get them out of our target cities. The best chance that the individual has for saving his life is by putting as much distance as possible between himself and ground zero. We are, therefore, attempting to substitute distance for shelter. In Civil Defense this principle is known as Evacuation.

To emphasize the seriousness of this situation, I should like to cite to you the figures on page 323, which indicate the damage that would result if hydrogen weapons were dropped on these target areas at their time of greatest vulnerability.

We have been working on this evacuation problem for about a year, and while we have something to show for our efforts, we have not nearly enough. It is not necessary, I think, to indicate to you that an operation, which attempts to move 3,000,000 people to safety under the most unfavorable circumstances and then provide for them for an indefinite period in inadequate surroundings, presents a problem of staggering proportions. If successful evacuation can be accomplished in our American cities, we are going to be faced with the biggest logistics problem that the world has ever known.

Here, briefly, is where we now stand in Massachusetts with regard to our evacuation plan:

The State has been divided into three types of zones: Evacuation, Neutral and Reception Zones. The size and extent of the zones to be evacuated was arrived at through a determination of the probable size of the weapons which would be used on it, to accomplish the greatest necessary destruction. These figures were concurred in by Federal Civil Defense and First Army. I indicated the size of these weapons just a moment ago: for Boston a 30-megaton bomb, for Worcester a 5-megaton bomb and for Springfield a 10-megaton bomb. If you are wondering why Springfield has a larger weapon estimated for it than, say, Worcester, which is actually a larger city, the reason is that Springfield has Westover Air Base, an SAC Base, in close proximity to it, and that it is why the value-rating of this target has been raised. Persons in these evacuation zones will leave by way of evacuation or escape routes. Such routes, marked with special evacuation signs, will permit of only one-way traffic—outward bound with no cross traffic. Although all possible means of transportation will be used, the private automobile is the basic method utilized for the movement of our population. Our plans do not call for any so-called walkouts, as such, but only for persons to walk to assembly points where they may be picked up by vehicles. The movement of

BOSTON AREA
(30-megaton bomb)

	A-Zone	B-Zone	C-Zone	D-Zone	Totals	% of total population
Miles Radius from Ground Zero	0-5. 7	5. 7-11. 4	11. 4-17	17-22. 8		
Estimated Daytime Population	1,100,000	800,000	200,000	100,000	2,200,000	
Killed	825,000	160,000	10,000	1,000	996,000	45.3%
Injured	165,000	240,000	50,000	9,000	464,000	21.1%
Safe	110,000	400,000	140,000	90,000	740,000	33.6%

WORCESTER AREA
(5-megaton bomb)

	A-Zone	B-Zone	C-Zone	D-Zone	Totals	% of total population
Miles Radius from Ground Zero	0-3. 1	3. 1-6. 3	6. 3-10. 1	10.1-12. 6		
Estimated Daytime Population	228,000	40,000	20,000	60,000	348,000	
Killed	171,000	12,000	1,000	600	184,600	52.8%
Injured	34,200	8,000	5,000	5,400	52,600	15.1%
Safe	22,800	20,000	14,000	54,000	110,800	32.1%

SPRINGFIELD AREA
(10-megaton bomb)

	A-Zone	B-Zone	C-Zone	D-Zone	Totals	% of total population
Miles Radius from Ground Zero	0-4	4-8	8-12	12-16		
Estimated Daytime Population	180,000	150,000	35,000	50,000	415,000	
Killed	135,000	45,000	1,750	500	182,000	44.2%
Injured	36,000	30,000	8,750	4,500	79,000	19%
Safe	9,000	75,000	24,500	45,000	152,500	36.8%

these people on evacuation routes will be out away from the city, through neutral zones into reception zones. No pre-assignment of evacuees to definite reception areas has yet been attempted.

The areas around the evacuation centers themselves are called "neutral areas," and are a ring of towns that either abut or are adjacent to the towns of the evacuation areas, or other urban areas that are not in the critical category. The zone is established for the organization and assembly of Civil Defense forces to combat the results of the disaster. Persons that live in this zone do not move, but stay in place, unless, of course, they desire to leave. Evacuees will pass through it to reception areas beyond. Unlike the old "duck and cover" plan, where seeking shelter was mandatory, there is no compulsion on the part of anyone to evacuate or take shelter, if he does not want to.

All other areas of the State are reception areas. These are the areas in which evacuees will be held, housed, clothed, and fed until their further distribution can be accomplished or until they can be returned to their homes. The reception areas in Massachusetts are not great enough to take care of the population, and consequently individuals will have to be moved into nearby states, principally New Hampshire and Maine. At the same time, Massachusetts will have to receive evacuees from Rhode Island. There is a possibility that some may have to be received from Connecticut and also, around the Pittsfield area, from New York state. In order to initiate planning on the local levels, a series of state directives called "Evacuation Memoranda" were issued from time to time. The most important of these was the second one that we issued—an outline of Massachusetts Civil Defense evacuation policy, which was, more or less, the blue print of the whole operation.

On February 24, the Governor issued Executive Order #31, which is the so-called Evacuation Order. This officially prescribes evacution of critical target areas as the official policy of the Commonwealth and in general sets forth the principles and methods under which this policy will be carried out. By today, every family in Massachusetts should have in its possession an instruction card, giving information as to the zone it occupies, what the attack warning signals are, and other necessary facts. How effective this would be today would depend upon how well the local community has developed its individual plan. In any event, incomplete though our plans are, we have now crossed the line from the old take-cover policy to that of evacuation. If an enemy attack should come today, we would attempt evacuation.

We have one other factor in this matter, and that is the Federal Survival Plan. This Survival Plan is a project which is underwritten by the Federal Civil Defense Administration. Its purpose is to make studies of various kinds that will allow a proper evacuation plan to be set up for a critical target area. In some cases the Survival Project involves more than one state—for example, the Greater New York area, where three states are involved. In the case of Massachusetts, where we have three target areas, the Federal Government, rather than indicate each target separately, has allowed us to make a plan for the whole state, since our target cities are so close together that, for all practical purposes, they constitute a single integrated operation. We feel in Massachusetts that we are as far along as probably any state in our evacuation planning. However, since some of our planning has been on a "best estimate" basis, we know that revisions will unquestionably be necessary. The Survival Plan will, we hope, give us the basic and definite facts and figures upon which we can base our final conclusions. This study will be developed by a special task force outside the Agency. The Survival Plan comes at a particularly good time for us, because we still have policy decisions that we absolutely cannot make until we have more specific facts and information on some of the factors involved in the plan. I feel certain that this is going to give us the firmest possible foundation upon which to build our final evacuation plan. The Survival Plan also requires that field exercises be run to prove out the plan, and this will be most welcome, for as yet Massachusetts has held no such test.

Now a word about natural disasters. As already stated, Civil Defense in Massachusetts has responsibility for natural disasters. In this regard, during the past three years, we have had much to do in this field and have built up a considerable experience in natural disaster operation. We had the Worcester Tornado in 1953, the hurricanes of 1954 and the major flood of 1955.

The 1955 flood was by far our largest natural disaster, and the fourth major natural disaster that Civil Defense had to combat in a little over two years. In my opinion, it was the best and most effective operation of any that we were engaged in from all standpoints. The mobilization and disposition of forces was speedy and reflect great crdit on local organizations. Communications were better organized and more effective than in the past. Our lines of command and authority were effective. Civil Defense could do little about averting the physical damage of the flood, but the results of its operations in rescue and evacuation showed up clearly in the low loss of life in Massachusetts—only some twelve people lost their lives. The most pleasing thing to me about the whole operation was that we got a fast start on it; we stayed on top of the situation throughout; and we were constantly thinking ahead, and anticipating actions to be taken. In short, we operated like a going concern.

In closing, I should like to refer very briefly to some of the problems that confront us. This is pretty much a new field that we are in. We are being called upon to perform an operation of military proportions with a volunteer organization, and not a very well trained one at that. This can only be offset by a more widespread realization of the necessity for grappling with the problem in official and private circles. Competent personnel is difficult to come by, and considerable training and education are necessary before an individual is of much value.

We are in a sense creating and developing at the same time. The march of events is often too rapid for a cumbersome organization like ours to keep step with. We are only now at our Agency beginning to develop a professional corps, competent for the work of Civil Defense.

The great problem which we live with day and night is: how much time have we in which to perfect our plans and develop our organization? Two years? Five years? That is the unanswerable question. It might be less rather than more. Certainly recent events tend to confirm this. I feel a strong sense of urgency and am consequently making our plans on the basis that time may be shorter than we think—and in Civil Defense we have a fearsome amount of work that still remains to be done.

WATER SUPPLY, FIRE FIGHTING AND CIVIL DEFENSE

BY FRANK P. McNEA*

[Presented March 15, 1956.]

It is my purpose today to attempt to develop a better understanding between water-supply officials and our fire chiefs on the necessity of closer coordination in natural disaster or civil defense emergencies.

Effects of nuclear attacks can be listed in three groups:

1. Blast effects.—These will be extensive but will be over in a few minutes.
2. Radiological effects.—These effects can be lethal following a burst, but will immediately start to decay and will diminish with time.
3. Thermal effects.—The thermal effects of the bomb, while extensive at the outset, will continue to increase its destructiveness. The important point to remember is that the bomb only sets the fire. The combustible material in the city provides the additional fuel. The fires, if not stopped, will in many cases burn out to open areas.

The services faced with the principal job of minimizing damage during the vital post-attack hours are the water-supply and fire service. The nation's fire service can be counted on to do their utmost, to cope with post-attack conditions, but despite any possible concentration of men and equipment, their success in containing mass fires will be based on the effectiveness and scope of the pre-attack water-supply program, and the full coordination of the water department and fire service during post-attack operations.

FIRE-SERVICE PROBLEMS

The atomic age has brought to the fire service problems of such immensity that peacetime fire-fighting forces and operational concept must be fully coordinated and greatly expanded. The conditions created by heavy attack with modern weapons must be thoroughly understood, in order to prepare a comprehensive operational plan for target areas.

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The basic facts to be considered are as follows:

1. That attack by nuclear bombs is now possible on any of our target cities.
2. That the use of incendiary bombs, high-explosive bombs, chemical bombs or war gases is probable on smaller targets or in conjunction with atomic and hydrogen bomb attacks.
3. The possible occurrence of fire storms and conflagrations, caused by atomic and incendiary bomb attacks.
4. That the fire-fighting forces must be in operation to control the spread of fire within the first three hours. This will require that fire-fighting forces be quickly available and that the movement and response of support forces must be preplanned and be as automatic as possible.
5. The expectation that numerous fires may be started by saboteurs in evacuated cities, to hamper post-attack operations, and that sabotage fires may also be expected in support areas, in order to reduce the quantity of fire equipment available for target-city defense.
6. Evacuation problems:
   - (a) The possibility that the evacuation of the population might, if not carefully planned, result in numerous fires, caused by the hasty shutdown of manufacturing plants and other establishments, and also by the hurried evacuation of homes and stores.
   - (b) The overcrowded conditions in the reception-area communities can be expected to result in numerous fires, caused by the violation of fire safety regulations, such as improvised cooking facilities, and particularly in cold weather, where improvised heating facilities would be necessary.
   - (c) Mutual-aid fire equipment may have great difficulty in reaching the target cities because of the heavy road traffic,

and alternate plans should be prepared for the use of railroad and other transportation facilities, for the movement of fire-defense forces for long hauls, and even for short hauls where the situation may require.

(d) Where the target area has been evacuated at the time of attack, the small fires in the fringe areas would have time to develop into sizable fires before they are attacked. The control of such fires will, therefore, require the service of trained teams, equipped with pumping apparatus and hose.

Radioactivity

(a) Fallout of radioactive particles from the local target area and the fallout resulting from attacks on other target areas may prevent or seriously delay fire-fighting activity and may also seriously interfere with the movement of support equipment.

(b) Water under good pressure can be used to reduce the radiological contamination of equipment, to reduce the contamination of front-line working areas in target cities, and also to decontaminate buildings, areas and facilities used for feeding and housing the evacuees in the reception areas. At the present time the local fire departments are the only organizations equipped to furnish this very important service.

(c) The radioactivity in many cases will prevent the individual fire fighters from working in front-line contaminated areas for long periods. This will require that the program for the recruitment and training of a large additional auxiliary force be expanded to meet this challenge.

Wartime Fires

Fire from atomic or super bombs will start from two causes:

(1) The primary thermal effect of the bomb; (2) fires resulting from destruction by blast of buildings and contents. Fire fighting will not be possible in the central core of damage directly surrounding ground zero. There the buildings will be flattened and swept by fires. Such fires will not, it is ex-

pected, be free-burning. It is in the areas surrounding this central core, where buildings will be damaged but partially left standing, where we believe that mass fires could develop. (We now believe that atmospheric inversion may be a controlling factor in determining whether these mass fires will develop into fire storms or conflagrations).

Fire Storms

A fire storm is a phenomenon which occurred in numerous attacks of the last war. It involved the almost instantaneous ignition of many buildings over a wide area. These initial fires coalesce and produce a thermal column or pillar which, in the absence of a strong ground wind, rises almost vertically. New air is pulled in at the base of the pillar, and this onrush of air can assume gale-like proportions.

Conflagrations

The conflagration as described in the wartime fires had the same set of conditions initially, but in the presence of a strong surface wind the column was pushed over more or less horizontally and spread fire in the direction of the wind. The movement of such a fire could be headed off in some cases by fire fighting, but in the last war the fire usually burned out to an open space. Such a fire generates an intense heat wave, that makes it impossible for the firemen to operate against the wind, and this heat wave will often ignite buildings several hundred feet in advance of those actually burning. The area ahead of the fire will also be showered with thousands of burning embers. The only effective stop for a conflagration of this magnitude is an open area sufficiently wide to permit the firemen to concentrate their efforts on the opposite side, or of sufficient width that the fire will not attack the buildings on the opposite side. Parks, rivers, and railroad embankments can provide some fire breaks. Solid walls or buildings of fire-resistant construction, or walls with adequate window protection, in conjunction with strong fire-fighting forces may provide a means of stopping the fire.

Reduction of Fire Potential

The fire service should utilize to the fullest extent the invaluable information contained in the reports of the National Board of Fire

Underwriters on the normal fire hazards of each city. These reports identify conflagration areas, based on the peacetime assumption that fires will start at one location and spread, dependent on the physical arrangement, combustibility and contents of the structures involved. The wartime premise, however, contemplates the almost instantaneous ignition of hundreds of fires, in areas which would not be considered conflagration areas in a peacetime analysis. This is one of the reasons why we are suggesting an extension of the work of the National Board in the making of Civil Defense Urban Area Analyses.

We must understand also that, whether fire storms occur or not, we shall have fire situations that will overtax the capacity of any possible aggregation of fire companies, and a knowledge of areas of greatest hazard will be invaluable in both pre-planning preparations and post-attack containment operations. By identifying the most hazardous areas we shall know where to put the greatest emphasis on fire-prevention measures. Such measures would include reduction in the size of large undivided fire areas; installation of sprinkler equipment with private water-supply and pumping facilities; greater use of incombustible roofing materials; provision for exposure protection; the elimination of all unnecessary combustible material; bricking up windows where feasible; installing wire glass in metal frames with outside sprinkler protection; reduction in size of lumber piles and greater spacing between piles; clearing areas that are exposed to forest and brush fires, and providing compartments and sprinkler protection for all inaccessible open spaces under piers and platforms.

A program should also be completed in each metropolitan area for the development of private fire-protection facilities and the organization, training and coordination of fire brigades in manufacturing and other facilities.

Fire officials should use the urban area analysis data to determine the areas that can be saved, areas that could be saved by adequate structural changes, if such changes are made now, and the areas in which fire fighting would be futile in the event of a mass fire. All these factors must be pre-evaluated to pre-plan all locations in a city in which a combination of fire breaks, favorable topography, superior construction and effective fire fighting can be expected to contain this type of fire.

Regular Water-Supply System

The fire service must be thoroughly familiar with the entire water-supply system of the metropolitan area.

The National Board of Fire Underwriters Report on each of our larger cities provides full information on the location and capacity of intakes, wells, and supply mains; location, arrangement and capacity of all pumping stations, reservoirs and storage tanks; the location and sizes of all primary feeder mains, and also the fire flow available at many specific locations.

It is extremely important that the chiefs of all target-city fire departments coordinate with the officials of the water departments in planning a program for the isolation of areas by closing valves on mains leading into the bombed-out areas. Such plans should include provisions for water supply as the fire forces advance into areas. This will require that valves within the area be closed and the outer valves opened.

Overlays of various-size A-B-C-D bomb-damage circles can be placed over the National Board maps of local water-supply systems, to evaluate the potential damage at various ground-zero locations. The results of such a study will indicate the need for increased facilities and for greater emphasis on auxiliary water supply.

High-Pressure System

In addition to the normal water-supply system, many of our large cities are equipped with a separate high-pressure system. These systems consist of large mains, large-size hydrants, ample water supply and pumping facilities, which are usually separate from the regular water-supply system. It is usually possible to provide full capacity at a pressure of 300 pounds from the hydrants in the congested high-value districts.

The chief will need to prepare plans for supplying this system in the event the high-pressure pumping facilities should be destroyed. He should map all locations where emergency connections could be used to provide water supply and pressure from fire-department pumpers, fire tugs, or portable FCDA water pumps.

Fire department pumpers cannot travel over heavy rubble. In the high-pressure areas the firemen could carry their hose and nozzles over the rubble and operate from high-pressure hydrants, if this system can be kept in operation and fully supplied.

Auxiliary Water Supplies

Plans for auxiliary water supply should be based on the probability that the regular water-supply system and high-pressure system will be put out of action by the attack.

The fire service will need to know and carefully map the location and capacity of all auxiliary water supplies. Where necessary, adequate provisions should be made at all locations to insure the availability of this water supply for fire-fighting purposes. The FCDA portable 8-in. steel pipe and pumps will be very valuable to the fire service if the following plans for close cooperation with the water officials are accomplished:

(a) A survey of the entire auxiliary water supply potential of the entire target area should be made and mapped. This should include all locations from which adequate emergency water supplies may be obtained.

(b) Coordinated plans should be made for the proper storage, prompt transportation and assembly of pipe, and operation under all forseeable conditions. This should include plans for developing above-ground systems of 8-inch mains into areas which may have the regular water mains valved off.

(c) All locations should also be mapped where heavy peacetime fire-fighting requirements would overtax the normal supply. The fire chief and water-department officials should develop plans for augmenting the supply at all such locations.

Attack with A-bombs or Conventional Weapons

It is logical to assume that an enemy would employ weapons other than H-bombs in attacks on strategic targets within this country. Certain urban areas may be subjected to attacks with A-bombs or conventional weapons. Where attacks of this nature were made, destructive fires would be the major residual hazard. Our fire defense must be planned to meet situations of this nature, in addition to those resulting from H-bomb attacks.

In a target area subjected to an H-bomb attack, aiming errors may leave important areas of the city undamaged by blast but exposed to mass fires. If residual radioactivity is within permissible tolerance, prompt fire-fighting operations may prevent destruction of important sectors.

Adjoining our target cities are many residential and business communities, manufacturing plants, storage of strategic materials, communication and transportation facilities, and other essential installations. Both the population and the resources of these areas would be exposed to the hazards of fire by direct extension from the target city, from sparks and burning brands, and from accidental causes, resulting from excitement and confusion following an attack of that nature. With adequate water supplies and prompt action of sufficient number of fire-fighting units, loss of human life could be minimized and valued resources protected.

Each fire-fighting unit must be equipped with radiological monitoring instruments and have sufficient trained personnel to determine and evaluate the hazard of residual radioactivity in its specific area. This will apply to all fire-fighting forces, because of the nation-wide fallout spread. Fire-fighting activities within areas exposed to radiological contamination will be governed by the amount of radioactivity. Fire-fighting units could render valuable services in fallout areas where decontamination by the application of water under pressure was feasible.

Post-Attack Operations

The fire chief will be faced with the problem created by a core of complete destruction at ground zero and a lessening amount of fire as the distance from "ground zero" increases. At the outer fringe of the burning area there will be other fires developing into area fires and small fires threatening to develop into large fires at various locations in the fringe area.

The fire forces will move into action with the fire companies in each area performing a continuing radiological monitoring of the location in which the fire fighters will work. The over-all monitoring functions will be performed more thoroughly by the civil defense teams assigned to A-B-C reconnaissance. The Civil Defense Director will keep all service chiefs informed on significant changes in the radiological field.

The main fire will be attacked at the outer perimeter and apparatus will be concentrated only at points where specific results can be obtained.

The hundreds of fires which we can expect in the periphery area indicate that fire apparatus in such areas will have to be used on a knock-down-and-move-on basis. The mopping up and overhaul operation can be performed by one or two wardens or trained civilian fire fighters, equipped with hand extinguishers and other small equipment. By this method of operation booster-equipped apparatus can hit several separate fires, reload the water tanks, and then continue to attack such fires which are beyond the extinguishing capability of wardens equipped only with hand extinguishers.

SUGGESTIONS ON WATER-WORKS PLANNING FOR CIVIL DEFENSE

The principal objective of water-works officials should be to provide (1) an adequate supply of water for fire fighting and for decontamination and (2) drinking water for casualties, Civil Defense workers and evacuees, and later an adequate supply for domestic and industrial use.

In order to plan intelligently, the water-works superintendent should be a member of the local Civil Defense organization and should act as an advisor to the Chief of Engineering Services in matters pertaining to the water works. He should, in the pre-attack period, make a survey of the entire water works to determine the weaknesses in the system. The hydraulics of the distribution system should be investigated, to locate possible bottlenecks to fire flows, and necessary corrections made. Gate valves on the distribution system should be overhauled and placed in good operating condition. A study should be made of the treatment process, to determine possible alternative emergency measures that could be initiated. A survey should also be made to locate potential auxiliary sources of water supply. These should be developed with the fact in mind that the demand for fire fighting after attack will be many times the normal demand. Key points on the distribution system should be located, which might be used as alternate points of emergency disinfection. The need for standby power generators, water-purification equipment and emergency portable or mobile chlorinators should be investigated, and suitable corrective action taken. Special provision should be made to supply water to mass care and feeding centers, first-aid stations, and emergency hospitals. The demands for these purposes would be small compared to the demands for fire fighting, but the water so provided must be safe, high-quality drinking water.

Corrective measures taken as a result of these surveys and studies would serve a dual purpose. They would strengthen the water works to meet extraordinary demands in disasters and improve its National Board of Fire Underwriters rating, which may result in lower insurance rates.

The training of employees and volunteers in the operation of the water utility will also be important. Existing employees should be trained to take key positions in repair crews and on treatment-plant and pumping-station operating teams. Auxiliary groups should be organized—recruited from contractors' crews, plumbers, sanitary engineers and other volunteers. These groups should be trained in the emergency repair and operation of water works in time of disaster, including the repair of broken water lines, closing of valves to isolate devastated areas, operation of standby power-generating equipment, use of alternative treatment processes in the existing water-treatment plants, and operation of portable water-purification units and portable chlorinators. Certain members of the operating teams should also be trained in water-sampling techniques, methods of chlorine-residual determinations, techniques of water-main sterilization, and methods of decontamination of water tanks and containers, used to haul water to emergency points of use.

In this pre-disaster survey thought must also be given to the important role existing water laboratories will play in time of emergency. The need for portable laboratory facilities, properly equipped for the detection and identification of biological, chemical and radiological warfare agents, should be carefully considered.

These are actions which the water-works superintendent can take now in preparing his own organization for disaster. He should then develop mutual aid plans with nearby cities and arrange for support from the more distant cities. Any target area that has been bombed will need help. They will be unable to cope with their water-supply problems alone. The mutual aid plans could be automatic.

They could be formulated so that certain water-works forces would respond immediately after an attack. However, much ground-work and training would be necessary before such a plan would work smoothly. Water-works employees of the mutual aid and support areas should be familiar with the water works of the stricken areas. They should have predesignated rendezvous sites and should be equipped to repair breaks, close valves or make emergency replacements. Water-works personnel are accustomed to meeting emergencies and will be able to function effectively after an atomic bombing. The State Civil Defense office should be requested to assist in the formulation of mutual aid and support plans.

These are suggestions of what can be done by water-works people in the pre-attack period. Any advance planning and corrective action taken before the attack will place the water works in a much better position to recover after attack and to meet the greater demands for water for fire fighting and later for domestic and industrial use. The Federal government places the responsibility for Civil Defense at the State and local level. The Federal Civil Defense Administration has the responsibility of providing guidance and assistance to the States and their political sub-divisions in preparing for Civil Defense. As a part of the plan to assist States and municipalities, Federal funds are available to FCDA, to be used on a fifty-fifty matching basis for the procurement of engineering equipment and supplies. This is called the FCDA Contributions Program.

The objectives of the FCDA engineering-equipment contributions program are to assist States and their political sub-divisions in establishing engineering resources required for Civil Defense activities and to make facilities available for trainng an adequate Civil Defense engineering force.

For the fiscal year 1955, FCDA participated in the procurement of engineering equipment and supplies only on a matching fund basis and will continue this program through fiscal years 1956 and 1957. Requests for such assistance must be initiated at the State or local level.

MEMOIR OF LANGDON PEARSE

Langdon Pearse, the son of John Barnard and Mary Langdon (Williams) Pearse, was born in Boston, Mass., on November 12, 1877. His preparatory education was in Roxbury Latin School up to 1895. He received the degree of A.B. from Harvard College in 1899. From Massachusetts Institute of Technology, he received the degrees of B.S. in Civil Engineering in 1901 and M.S. in "Studies in Sanitary Science and Advanced Structures" in 1902.

His early experience consisted of several positions on water-supply projects in New England and New York. From 1904 to 1907, he was assistant engineer on water works and sewage works for Columbus, O. In 1907-1908, he was assistant engineer for Peoples Water Co. of Oakland, Cal.

In February, 1909, he was employed by The Sanitary District of Chicago (now The Metropolitan Sanitary District of Greater Chicago) as Assistant Engineer, became Division Engineer later, and from 1921 to the time of his death on July 20, 1956, was Sanitary Engineer. Mr. Pearse's primary assignment with the Sanitary District was to develop means of artificial sewage treatment to supplement the dilution method, which had been in use since completion of the Chicago Sanitary and Ship Canal and reversal of the Chicago River in 1900. There were meager data on large-scale sewage treatment at the time; the activated-sludge process had not been developed. Under Mr. Pearse's direction, pilot treatment plants of various types were operated on domestic sewage, packinghouse wastes, tannery wastes, corn-products refinery wastes, and paint wastes, up to 1928. These pilot plants included much pioneering in the activated-sludge process. The designs of the Sanitary District's great sewage-treatment works, including the world's largest, were based largely on data obtained from the pilot plants. Mr. Pearse was an avid collector of data, from any available source in the world, in addition to the investigations under his direction. Prior to 1925, he was also in charge of treatment-plant design. Also, Mr. Pearse handled the sanitary engineering aspects of the Lake Diversion question, which has been intermittently before the United States Supreme Court from 1922 to 1950, and the Congress from 1918 to date.

In addition to his work for the Sanitary District, Mr. Pearse was a prolific writer of articles for technical publications and was active in committee work of the professional societies. He served for 10 years as Chairman of the Committee on Sewerage and Sewage Treatment of the American Society of Civil Engineers, and for 20 years as Chairman of the Committee on Sewage Treatment of the American Public Health Association. Also, he was one of the founders of the Federation of Sewage and Industrial Wastes Associations, chairman of several of its committees, and a continuous adviser.

Mr. Pearse was a member of many learned and professional societies, including American Society of Civil Engineers, American Institute of Consulting Engineers, Institute of Civil Engineers (England), Institute of Sanitary Engineers (England), The Engineering Institute of Canada, Western Society of Engineers, American Public Health Association, New England Water Works Association (since 1912), American Water Works Association, Federation of Sewage and Industrial Wastes Associations, American Academy of Arts and Sciences, and Phi Beta Kappa. Also, he was a member of the University Club (Chicago) and Indian Hill Club.

Langdon Pearse was an outstanding example of a gentleman with independent means, who might have indulged in a life of ease and pleasure but, instead, worked assiduously in a creative field for the benefit of mankind.

On June 1, 1910, he was married to Eleanor Howard Dean. He is survived by his widow.

NORVAL E. ANDERSON AND H. P. RAMEY

REPORT OF COMMITTEE ON RAINFALL AND YIELD OF DRAINAGE AREAS

RAINFALL IN NEW ENGLAND*

PART V. RAINFALL IN RHODE ISLAND

AUSTIN, R. I.
Record: October, 1940, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	—	—	—	—	—	—	—	—	—	1.41	6.43	2.46	—
1941	2.85	3.07	2.37	1.63	5.85	4.70	5.35	2.51	0.89	2.15	3.97	3.74	39.08
1942	3.48	5.10	8.24	0.90	1.56	2.51	5.34	5.02	2.34	3.65	4.25	4.35	46.74
1943	3.20	1.72	—	3.00	5.56	—	3.80	2.82	0.52	6.51	5.00	1.44	—
1944	2.52	—	6.87	3.57	1.61	4.64	0.70	2.36	9.86	2.35	12.64	3.63	—
1945	—	4.28	2.00	3.12	4.54	4.37	1.18	3.40	2.19	2.83	10.11	7.04	—
1946	4.36	3.48	1.79	2.20	4.46	3.29	2.12	12.24	1.01	2.30	0.77	—	—
1947	3.64	1.54	4.29	3.78	5.18	3.60	2.78	—	2.48	3.70	6.47	3.23	—
1948	5.54	2.62	4.02	4.29	10.12	3.74	2.95	1.04	0.44	3.89	5.29	2.25	46.19
1949	4.37	4.13	2.83	5.94	3.49	0.00	1.91	3.12	5.11	1.86	3.41	2.94	39.11
1950	3.56	4.84	4.02	4.52	3.87	2.79	2.12	4.34	1.97	2.70	7.79	4.42	46.94
Av. 5 yrs.	3.96	3.95	4.30	3.46	4.98	2.75	3.53	3.21	2.15	2.85	4.94	3.54	43.62

BLOCK ISLAND, R. I.—Elevation 26 feet
Record: January, 1878, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.03	2.52	6.20	0.85	1.73	1.64	2.73	5.70	1.85	3.60	4.46	5.36	40.67
1943	2.90	1.95	3.38	3.33	2.36	1.59	4.01	2.42	1.65	2.53	2.92	2.07	31.11
1944	3.04	1.64	5.19	5.05	1.26	2.94	0.42	2.06	3.66	1.89	9.73	3.14	40.02
1945	3.46	5.16	1.61	2.43	4.39	1.88	2.30	2.00	0.84	2.31	6.84	6.29	39.51
1946	4.50	2.44	1.88	2.38	4.19	2.80	1.54	8.08	1.90	0.22	0.86	3.23	34.02
1947	3.54	1.66	3.37	5.86	3.71	3.32	4.73	0.69	2.80	3.28	3.67	3.04	39.67
1948	5.54	3.19	4.75	4.67	8.37	2.50	2.27	0.98	1.01	3.28	4.33	2.59	43.50
1949	4.94	6.30	3.55	3.42	2.93	T	0.96	3.71	1.53	0.92	3.18	3.54	34.98
1950	3.14	3.94	2.91	2.67	3.33	2.13	2.83	2.62	0.40	1.14	3.91	2.99	32.01
Av. 73 yrs.	3.77	3.47	3.82	3.54	3.25	2.74	2.86	3.48	2.79	3.30	3.59	3.70	40.31

BRISTOL, R. I. (Bristol County Water Co.)
Record: January, 1930, to December, 1942

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1930	3.03	3.11	2.28	1.18	2.34	1.86	2.24	3.53	0.84	3.58	3.77	2.01	29.77
1931	3.63	1.78	4.67	2.62	4.79	4.43	3.84	3.27	1.61	3.50	1.01	3.30	38.45
1932	4.88	1.55	4.82	1.23	2.44	2.47	2.21	4.59	5.74	5.56	5.51	1.48	42.48
1933	1.70	3.22	4.24	6.99	2.78	2.79	1.39	3.60	8.31	2.61	1.78	2.93	42.34
1934	3.65	2.89	2.75	4.59	2.99	3.53	0.79	2.74	3.12	3.11	3.25	2.13	35.54
1935	5.03	2.69	1.54	1.95	1.90	4.59	2.62	1.96	3.02	0.72	4.48	0.95	31.45
1936	5.98	3.16	7.26	2.38	0.88	3.01	1.99	4.54	4.95	3.19	1.08	10.59	49.01
1937	3.90	1.76	1.75	5.00	2.55	4.46	0.71	4.33	2.71	3.79	6.07	3.44	40.47
1938	3.60	1.92	2.13	3.12	3.54	6.77	6.12	3.96	6.52	2.78	2.53	3.20	46.19
1939	2.58	4.51	5.20	5.18	0.60	3.79	1.45	4.03	2.73	4.38	0.66	2.74	37.85
1940	2.31	3.10	2.49	5.27	4.93	1.56	5.41	0.82	3.40	2.16	7.20	2.61	41.26
1941	2.62	1.87	1.52	1.33	3.23	4.89	4.10	2.57	0.70	1.93	2.19	2.54	29.49
1942	2.64	2.15	3.85	0.43	1.68	1.67	3.69	5.94	1.61	3.85	4.60	3.01	35.12
Av. 13 yrs.	3.50	2.59	3.42	3.17	2.67	3.52	2.81	3.53	3.48	3.17	3.39	3.15	38.42

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* Continued from this JOURNAL 70:2, 216, June, 1956.

FOSTER, R. I. (Hopkins Mills, Providence Water Works)—Elevation 450 feet
Record: January, 1916, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	5.22	3.14	8.72	0.74	3.37	3.63	5.14	4.30	1.68	4.59	5.06	7.35	52.94
1943	3.66	2.17	3.92	3.88	3.88	1.78	2.94	2.18	1.17	6.52	4.35	1.41	37.86
1944	1.84	2.39	5.12	4.37	1.41	4.05	2.19	2.01	10.77	2.45	7.78	4.01	48.39
1945	3.52	6.60	2.05	3.82	5.22	4.32	3.27	2.93	2.73	2.29	9.32	8.51	54.58
1946	4.80	4.20	1.55	2.21	4.82	3.28	3.17	9.72	5.07	0.38	1.55	4.01	44.76
1947	3.13	4.19	3.79	5.53	3.78	3.90	5.87	2.32	4.78	2.47	6.28	5.54	51.58
1948	10.19	2.98	4.40	3.99	9.58	4.58	3.68	3.53	1.43	4.23	7.04	3.69	59.32
1949	4.33	4.11	2.81	4.19	4.33	0.12	1.23	8.16	3.77	2.53	3.24	3.11	41.93
1950	3.80	4.61	3.85	3.60	4.03	2.94	2.09	4.85	1.68	2.47	6.92	4.58	45.42
Av. 35 yrs.	4.21	3.73	4.27	4.06	3.73	3.90	4.12	4.50	4.17	3.28	4.57	3.96	48.50

GREENVILLE, R. I.
Record: January, 1940, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	2.86	2.86	4.16	5.87	6.13	4.38	4.35	2.00	2.76	2.06	7.60	2.12	47.11
1941	2.66	2.46	3.10	1.26	3.36	3.52	6.57	2.24	1.47	1.52	4.21	4.15	36.52
1942	3.49	4.29	7.32	0.74	3.38	4.88	5.85	4.61	2.02	4.06	5.84	6.00	52.48
1943	3.40	1.62	3.14	3.84	4.18	2.10	3.91	1.89	1.37	7.17	3.93	1.66	38.21
1944	1.45	2.04	4.92	4.99	1.03	4.12	1.32	1.14	9.80	2.91	8.95	3.24	45.91
1945	3.28	3.71	2.30	3.61	6.34	5.61	3.32	3.41	2.75	2.41	8.88	6.89	52.51
1946	3.69	2.68	1.70	2.71	5.45	4.10	2.91	11.85	3.44	0.44	1.63	3.46	44.06
1947	2.57	2.09	2.99	5.49	4.88	4.63	3.61	2.80	5.87	2.99	7.08	3.20	48.20
1948	5.31	1.49	3.65	4.40	9.97	4.40	6.17	2.86	2.05	5.36	8.08	2.43	56.17
1949	3.67	2.07	2.66	4.08	4.09	0.25	0.93	3.46	5.04	2.59	3.80	2.31	34.95
1950	3.17	3.70	4.37	3.80	3.40	3.65	1.89	6.43	2.39	2.37	7.95	4.93	48.05
Av. 11 yrs.	3.23	2.63	3.66	3.71	4.75	3.51	3.71	3.88	3.54	3.08	6.18	3.67	45.56

JOHNSTON, R. I. (Neutaconkamut Res., Providence Water Supply)
Record: February, 1929, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.10	3.18	7.01	0.79	1.90	3.25	4.51	4.55	1.73	3.37	4.85	5.74	43.98
1943	3.05	1.62	2.98	3.76	4.23	2.31	2.28	1.06	1.38	5.41	2.34	1.15	31.57
1944	1.79	1.94	4.13	4.02	1.27	3.70	0.84	1.42	11.47	3.37	7.77	2.99	44.71
1945	2.10	5.35	1.91	2.67	3.85	4.69	2.11	2.90	2.88	2.34	7.07	7.59	45.46
1946	3.22	3.17	1.53	2.29	4.19	2.89	1.60	12.90	1.95	0.37	0.96	3.71	38.78
1947	2.92	1.47	3.11	4.95	3.30	4.10	3.64	3.29	3.15	3.15	5.34	2.80	41.22
1948	7.11	1.76	3.65	3.99	9.25	4.13	4.41	3.44	1.80	4.96	5.70	2.25	52.45
1949	4.02	3.64	1.89	5.85	3.58	0.07	0.96	3.72	3.19	2.29	3.67	1.95	34.83
1950	3.27	4.18	3.85	3.14	3.05	1.99	0.89	5.51	1.95	2.88	7.60	4.54	42.85
Av. 21 yrs.	3.73	2.98	4.10	3.72	3.47	3.55	2.85	3.74	3.80	3.12	4.23	3.54	42.83

KINGSTON, R. I.—Elevation 250 feet
Record: January, 1889, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.61	4.60	7.10	0.72	1.72	2.65	4.26	6.00	2.21	4.27	5.19	6.38	48.71
1943	3.48	2.10	2.60	3.33	3.61	1.40	2.69	2.63	1.20	4.57	2.66	1.54	31.76
1944	2.03	1.82	5.61	3.32	0.76	2.10	0.67	1.82	6.10	2.46	9.90	2.89	39.48
1945	3.14	3.18	2.28	2.59	4.86	2.84	1.22	3.83	1.25	2.33	8.16	7.17	42.85
1946	4.47	2.60	1.73	2.53	4.77	2.83	2.04	11.12	2.24	0.57	0.96	3.38	39.24
1947	3.41	0.67	3.33	5.26	4.42	3.31	4.79	1.62	2.35	3.60	6.12	2.80	41.68
1948	5.79	2.77	4.43	4.20	8.61	2.37	1.87	0.79	0.96	4.22	4.52	2.20	42.73
1949	5.22	4.39	2.58	4.57	2.63	0.04	1.89	2.51	4.02	1.60	3.40	3.00	35.85
1950	3.55	3.97	3.46	2.14	3.02	2.00	1.18	2.94	1.28	1.56	6.76	3.55	35.41
Av. 62 yrs.	4.64	4.05	4.55	4.38	3.84	3.33	3.20	4.17	3.62	3.84	4.38	4.44	48.44

NEWPORT, R. I. (Main Pumping Sta., Newport Water Works)
Record: January, 1901, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1901	2.08	0.52	7.11	7.04	7.09	2.53	2.65	2.90	3.68	3.60	1.72	8.36	49.28
1902	1.55	3.50	5.75	3.08	1.42	4.86	2.75	1.79	3.35	4.37	1.12	5.59	39.13
1903	3.49	4.60	8.09	4.92	0.94	5.78	1.90	3.77	1.23	2.98	2.30	2.93	42.93
1904	2.74	3.12	1.63	8.25	2.36	4.83	2.40	4.91	2.08	1.41	2.42	2.89	39.04
1905	2.83	1.50	2.70	2.16	1.82	7.52	3.21	4.77	4.68	1.86	2.69	3.60	39.34
1906	3.27	3.94	5.94	2.92	4.76	2.51	4.29	1.82	6.31	5.52	2.84	3.35	47.47
1907	3.74	1.83	1.83	3.49	5.03	1.65	0.65	0.93	8.03	2.29	5.19	4.71	39.37
1908	2.57	3.27	1.61	1.04	3.67	2.82	1.85	6.44	0.81	5.74	1.26	4.18	35.26
1909	4.04	5.74	2.77	6.21	3.52	2.00	0.82	1.98	3.06	1.74	3.58	2.26	37.72
1910	4.55	4.04	1.79	1.79	2.87	3.51	2.52	2.47	2.92	1.73	3.93	2.40	34.52
1911	3.39	1.59	2.50	4.32	1.17	1.68	4.08	6.70	2.65	2.92	7.25	3.61	41.86
1912	3.09	3.00	8.17	4.22	4.29	0.32	1.20	3.37	2.51	1.27	3.19	6.45	41.08
1913	5.77	3.64	3.69	6.86	2.54	1.42	1.26	3.77	2.68	7.87	2.40	4.29	46.19
1914	2.91	2.23	4.43	4.09	3.10	1.04	5.33	3.42	0.73	3.27	2.15	5.10	37.80
1915	10.02	3.67	0.11	1.68	2.91	1.61	1.81	6.24	1.45	4.96	2.08	4.62	41.16
1916	1.36	5.07	1.77	4.08	3.82	4.30	9.40	2.93	1.10	2.38	2.95	2.51	41.67
1917	2.98	3.84	5.33	2.41	4.36	4.96	1.23	3.40	3.49	4.84	0.33	1.74	38.91
1918	3.14	3.07	2.24	4.58	1.95	3.96	2.31	3.00	3.54	0.91	1.87	2.61	33.18
1919	4.13	3.81	3.89	3.21	3.87	3.58	7.68	7.00	5.85	1.75	3.52	2.98	51.27
1920	2.74	8.09	5.04	6.20	4.92	6.71	2.00	1.93	2.16	2.82	3.02	3.99	49.62
1921	2.70	1.55	3.50	4.57	3.27	2.49	5.69	2.92	1.20	1.60	7.74	2.17	39.40
1922	2.87	3.49	4.76	2.99	3.20	2.96	2.66	9.47	1.20	3.40	0.37	3.94	41.71
1923	5.18	1.56	5.33	5.35	1.33	4.13	2.16	2.07	3.02	4.69	2.25	5.93	43.00
1924	4.36	2.46	2.42	4.40	2.02	2.35	1.13	7.49	4.63	0.31	1.99	2.81	36.37
1925	2.68	1.91	3.37	2.07	4.31	2.75	3.19	1.72	4.51	5.27	3.75	3.17	38.70
1926	3.18	4.33	3.46	2.15	5.06	2.32	3.71	4.30	1.24	6.27	5.64	2.66	44.32
1927	2.67	2.69	1.95	2.23	3.04	4.44	5.10	11.50	4.86	4.81	4.04	5.47	52.80
1928	2.33	4.23	3.68	5.80	2.10	5.88	4.39	1.78	6.34	3.29	2.75	3.41	45.98
1929	3.73	3.85	5.56	8.95	3.74	0.94	2.12	5.37	4.86	2.63	3.93	6.37	52.05
1930	3.82	3.76	2.44	1.39	3.43	2.18	3.11	3.11	0.85	5.05	5.18	3.36	37.68
1931	3.62	2.76	6.12	2.96	5.77	4.63	3.38	3.95	1.50	4.01	1.02	3.95	43.67
1932	6.27	2.20	5.23	1.37	2.27	2.46	1.44	3.80	6.44	5.26	6.06	2.28	45.08
1933	2.48	3.60	5.54	7.00	1.98	2.80	1.22	4.36	9.01	2.00	2.92	2.82	45.73
1934	3.31	3.36	3.16	3.92	3.37	2.84	1.46	2.01	2.10	3.59	2.13	3.24	34.49
1935	5.11	3.01	2.24	3.88	1.59	4.46	3.09	2.72	5.25	1.60	5.30	1.07	39.32
1936	5.90	2.68	6.30	3.03	0.78	3.86	2.65	3.32	5.91	2.00	1.13	10.00	47.56
1937	4.35	1.11	4.35	5.08	2.24	4.81	0.37	5.00	3.51	3.18	4.17	3.66	41.83
1938	3.16	2.17	2.67	3.61	4.28	7.01	2.75	2.32	6.19	3.17	3.51	3.52	44.36
1939	3.84	5.74	5.40	4.34	0.79	2.88	0.74	4.88	2.10	4.41	1.18	2.09	38.39
1940	2.15	4.96	3.51	6.22	3.52	1.53	3.48	0.56	3.09	2.47	7.58	2.87	41.94
1941	4.00	2.09	2.74	1.73	1.20	5.85	4.22	2.72	0.20	1.99	2.47	2.88	32.09
1942	3.61	2.82	6.48	0.64	2.37	1.83	3.39	7.79	2.05	3.88	5.09	4.18	44.13
1943	3.00	1.65	3.19	3.11	2.76	1.22	2.10	3.14	1.09	3.32	2.44	1.58	28.60
1944	3.86	1.67	4.46	4.52	0.99	1.45	0.42	1.81	4.99	2.10	8.74	2.65	37.66
1945	2.97	3.88	2.39	1.73	3.23	2.44	1.03	3.59	1.93	2.95	7.52	7.09	40.45
1946	4.81	1.81	1.86	2.10	4.99	2.51	1.31	10.92	2.37	0.39	0.83	3.21	37.11
1947	1.71	0.69	3.23	6.66	3.12	3.40	3.82	2.16	2.53	3.29	3.90	3.64	38.15
1948	5.42	2.26	3.81	3.76	8.67	2.30	1.45	1.15	1.50	3.75	5.22	2.27	41.56
1949	4.59	4.29	2.60	4.38	3.80	0.00	1.48	2.50	2.49	1.00	3.13	2.59	32.85
1950	4.27	4.25	4.40	2.56	2.36	1.70	1.11	2.49	0.94	1.56	5.39	3.65	34.68
Av. 50 yrs.	3.65	3.14	3.85	3.90	3.16	3.16	2.67	3.89	3.21	3.14	3.46	3.73	40.97

NEWPORT, R. I. (Lawton Valley Sta. Newport Water Works)
Record: April, 1944, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1944	—	—	—	5.11	1.25	2.46	0.43	1.27	5.17	2.52	3.45	2.29	—
1945	2.49	2.19	1.92	2.44	3.80	3.05	1.43	3.86	1.71	3.37	8.76	7.88	42.90
1946	4.32	1.91	2.11	2.39	4.67	2.67	1.72	12.47	2.54	0.66	1.10	3.51	40.07
1947	3.58	0.50	2.84	6.36	3.76	4.06	3.63	3.37	2.13	3.77	4.48	2.94	41.42
1948	5.08	2.57	3.67	3.60	9.36	2.78	1.75	1.13	1.16	4.79	6.00	1.77	43.66
1949	4.71	3.76	3.08	7.24	3.45	0.07	1.57	1.85	2.14	1.06	3.05	3.26	35.24
1950	4.87	4.20	4.10	2.82	2.98	2.51	1.50	3.03	0.94	1.61	6.01	4.07	38.64
Av. 6 yrs.	4.18	2.52	2.95	4.14	4.67	2.52	1.93	4.28	1.77	[illegible]	4.90	3.90	40.30

PAWTUCKET, R. I. (Diamond Hill Reservoir, Bd. of Public Works)—Elevation 220 feet
Record: January, 1901, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	5.23	3.02	7.70	0.75	1.31	3.70	5.28	2.82	1.75	3.72	3.13	4.68	43.09
1943	4.63	0.93	3.15	3.67	3.74	1.97	3.94	1.88	0.68	5.27	2.61	1.03	33.50
1944	1.68	2.85	4.47	3.86	0.85	4.30	1.05	1.04	9.22	2.97	6.12	3.46	41.87
1945	4.96	5.13	0.82	3.08	3.90	6.70	3.81	3.20	2.90	2.21	6.32	8.09	51.12
1946	2.46	3.28	1.55	2.04	4.08	2.94	1.10	9.33	2.68	0.34	1.13	3.40	34.33
1947	2.26	1.88	2.47	3.34	5.26	3.89	4.84	1.17	3.14	1.80	5.70	2.58	38.33
1948	5.23	2.12	3.54	3.52	8.00	3.03	6.47	4.72	1.54	4.89	6.11	3.04	52.21
1949	3.01	1.84	2.78	4.85	4.09	0.15	0.71	2.38	5.01	2.00	2.95	1.89	31.66
1950	3.63	4.79	3.52	2.86	2.37	1.97	1.39	4.23	0.80	1.50	7.38	3.81	38.25
Av. 50 yrs.	3.88	3.47	4.10	3.84	3.23	3.39	3.67	3.49	3.53	3.12	3.58	3.83	43.13

PAWTUCKET, R. I. (City Hall—Formerly Masonic Bldg.)—Elevation 140 feet
Record: January, 1901, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.63	3.42	6.34	0.93	2.26	4.19	4.77	5.12	1.88	3.23	5.39	5.49	46.65
1943	4.04	1.26	3.59	3.51	3.96	2.44	2.30	1.28	0.90	5.31	2.32	1.09	32.00
1944	2.09	2.36	3.92	4.36	0.80	5.26	1.22	0.88	9.49	3.60	6.75	3.01	43.74
1945	4.47	4.56	1.86	2.61	3.82	6.31	2.44	2.91	2.76	2.63	8.58	7.68	50.63
1946	3.51	3.24	1.40	2.43	4.45	2.94	1.15	10.23	1.74	0.20	0.50	3.67	35.46
1947	2.42	1.47	2.87	4.26	4.94	4.59	4.92	3.37	2.80	2.06	5.34	3.62	42.66
1948	5.73	1.91	3.83	2.69	8.72	3.85	5.24	2.22	2.26	4.92	4.32	1.98	47.67
1949	3.57	4.14	3.22	5.13	3.58	0.13	0.93	1.93	3.30	2.16	3.96	1.61	33.63
1950	3.79	4.69	3.63	2.98	2.73	2.49	1.39	5.50	3.20	2.88	5.44	4.31	43.03
Av. 50 yrs.	3.94	3.54	4.03	3.81	3.24	3.60	3.64	3.77	3.60	3.14	3.53	3.93	43.80

PROVIDENCE, R. I. (U. S. Weather Bureau)—Elevation 182 feet
Record: January, 1905, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.98	3.84	7.98	0.72	1.77	3.44	4.56	4.54	1.68	3.09	5.03	6.39	47.02
1943	4.07	1.61	3.74	3.72	3.34	1.88	1.97	0.82	1.24	4.39	2.32	1.15	30.25
1944	2.58	2.52	5.00	3.82	1.86	4.16	0.96	1.34	9.74	3.33	7.52	3.42	45.25
1945	4.08	4.26	2.21	2.57	4.25	3.97	1.98	2.63	1.87	2.29	8.50	7.82	46.43
1946	3.63	3.55	1.49	2.25	3.99	2.91	1.25	12.24	1.70	0.16	0.67	3.84	37.68
1947	2.85	1.83	3.36	4.91	3.73	3.93	4.71	2.01	2.96	2.27	5.42	3.73	41.71
1948	6.15	2.34	3.73	3.71	9.25	3.50	5.13	2.15	2.36	4.85	5.00	2.30	50.47
1949	4.23	3.66	2.32	5.17	3.47	0.04	0.96	3.23	3.42	1.98	3.27	1.86	33.61
1950	3.73	4.44	3.84	2.88	2.15	1.97	0.98	5.66	1.88	2.77	6.89	4.27	41.46
Av. 46 yrs.	3.60	2.96	3.40	3.35	3.05	3.07	3.12	3.47	3.20	2.78	3.33	3.43	38.76

PROVIDENCE, R. I. (Airport)
Record: December, 1940, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	—	—	—	—	—	—	—	—	—	—	—	2.34	—
1941	2.93	2.08	2.18	1.63	2.29	5.96	5.56	2.78	0.89	1.50	3.02	3.37	34.19
1942	3.98	3.84	7.56	0.61	1.53	2.05	5.27	4.79	1.78	3.31	4.99	5.77	45.48
1943	4.05	1.77	3.23	3.66	4.18	1.68	2.03	2.03	1.06	4.84	2.62	1.24	32.39
1944	2.38	2.17	5.25	3.84	1.28	3.09	0.62	2.17	7.95	3.28	7.66	3.03	42.72
1945	3.00	3.51	2.00	2.54	3.96	3.78	1.24	2.42	1.63	2.45	8.00	7.03	41.56
1946	3.38	3.24	1.60	1.84	4.46	2.77	1.21	12.77	1.87	0.33	0.68	3.68	37.88
1947	2.95	1.01	3.74	5.41	3.57	4.13	4.05	1.91	3.90	3.39	5.95	2.99	43.00
1948	6.00	2.21	3.50	3.86	10.58	2.73	4.93	2.88	1.41	4.14	4.65	2.34	49.23
1949	4.35	3.48	1.97	4.85	2.72	0.05	1.56	4.73	4.85	2.11	2.96	2.02	35.65
1950	3.51	3.83	3.79	2.92	2.51	2.02	1.42	3.60	2.09	2.71	6.89	4.22	39.51
Av. 10 yrs.	3.65	2.71	3.48	3.12	3.70	2.83	2.79	4.01	2.74	2.81	4.74	3.57	40.15

SCITUATE, R. I. (Fiskville—Formerly Cranston)—Elevation 260 feet
Record: March, 1916, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	5.24	3.99	8.52	0.97	1.64	3.63	5.74	4.49	2.02	3.20	5.06	7.39	51.89
1943	3.90	1.49	3.62	4.06	4.28	1.60	2.13	2.82	1.58	5.92	3.36	1.09	35.85
1944	1.77	2.57	5.31	4.45	1.82	3.25	1.72	3.39	10.26	2.96	9.54	4.80	50.84
1945	3.70	5.96	2.10	4.24	5.12	5.48	2.87	2.90	2.80	2.37	9.12	7.93	54.59
1946	5.01	4.17	0.79	2.86	4.90	3.35	2.13	13.23	2.93	0.53	1.36	4.10	45.36
1947	2.73	2.11	4.06	5.82	3.23	4.13	4.19	4.27	2.79	4.72	6.10	4.10	48.30
1948	7.84	2.77	4.37	4.22	9.57	4.06	4.70	3.09	1.55	5.54	6.15	3.23	57.09
1949	4.63	3.37	2.18	6.04	3.90	0.07	1.68	5.75	3.65	2.17	3.70	2.91	40.05
1950	3.57	4.41	4.45	3.36	2.89	2.57	1.60	4.70	1.99	2.56	7.62	4.68	44.40
Av. 34 yrs.	4.26	3.58	4.26	4.18	3.51	3.70	3.31	4.32	3.81	3.26	4.61	4.01	46.81

SCITUATE, R. I. (Rocky Hill)—Elevation 440 feet
Record: January, 1916, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.79	2.89	8.43	0.98	3.38	5.01	5.47	4.68	1.90	4.54	5.35	6.34	53.76
1943	3.39	2.09	3.78	3.46	3.97	2.09	4.58	1.93	1.02	5.60	4.05	1.14	37.10
1944	1.71	2.61	5.12	3.93	1.23	4.57	1.81	1.39	8.31	3.12	8.09	4.11	46.00
1945	3.17	6.33	2.52	3.42	5.59	5.10	3.08	3.32	2.83	2.29	8.24	6.34	52.23
1946	3.74	3.66	1.52	2.80	5.02	3.45	2.69	11.57	4.19	0.42	1.34	4.07	44.47
1947	3.15	2.29	3.61	4.65	3.62	4.85	5.76	2.35	5.36	3.17	6.45	3.19	48.45
1948	5.52	2.37	3.97	3.89	9.33	4.44	4.19	3.50	2.41	5.10	8.12	3.70	56.54
1949	4.43	3.80	2.36	4.15	4.32	0.17	1.10	6.78	3.80	2.58	3.61	2.68	39.78
1950	3.84	4.75	3.66	3.51	3.23	3.26	2.37	5.63	2.13	2.07	7.70	4.73	46.88
Av. 35 yrs.	3.90	3.49	3.97	3.81	3.64	4.02	3.91	4.44	3.89	3.13	4.43	3.61	46.24

SCITUATE, R. I. (North Scituate)
Record: January, 1926, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.97	3.13	7.95	1.03	2.83	4.42	5.28	4.47	2.07	4.64	5.66	6.43	52.88
1943	3.60	1.71	3.81	4.95	4.22	2.11	3.80	1.88	1.79	6.61	3.73	1.15	39.36
1944	1.56	2.62	4.89	4.53	1.28	3.81	1.77	2.45	12.17	3.06	9.04	4.66	51.84
1945	3.68	5.93	1.91	3.52	5.25	5.25	2.79	3.13	2.76	2.33	10.00	7.81	54.36
1946	3.52	3.81	1.32	2.49	5.46	3.47	2.89	12.75	3.59	0.58	1.48	4.06	45.42
1947	2.74	2.17	4.62	5.50	3.39	3.96	3.90	2.98	3.55	3.42	6.30	3.82	46.35
1948	7.98	2.70	4.48	4.21	10.00	4.24	3.52	2.99	1.32	5.18	8.07	3.64	58.33
1949	4.27	3.30	2.66	4.89	4.04	0.07	0.98	5.39	3.24	2.17	3.53	2.83	37.37
1950	3.70	4.73	4.53	4.02	3.78	3.32	1.59	4.86	2.39	2.07	7.04	4.50	46.53
Av. 25 yrs.	4.20	3.75	4.37	4.02	3.56	3.91	3.55	4.55	4.16	3.47	5.13	4.04	48.71

SCITUATE, R. I. (Westcott)
Record: August, 1928, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	5.05	3.57	8.39	0.81	2.71	3.51	5.24	3.82	1.80	3.92	6.44	5.48	50.74
1943	3.72	1.98	3.37	3.48	3.96	2.11	3.48	2.49	1.24	6.39	2.50	1.22	35.94
1944	1.89	2.63	5.14	3.91	1.37	3.25	1.83	1.71	11.73	2.52	8.47	4.81	49.26
1945	3.72	4.84	1.88	3.16	4.56	5.66	2.50	2.94	2.34	2.06	8.88	7.28	49.82
1946	3.40	3.64	1.24	2.36	4.98	3.23	2.54	12.15	3.69	0.49	1.34	3.77	42.83
1947	2.72	2.81	2.76	5.56	2.92	3.82	5.00	3.08	3.53	3.85	5.81	3.89	45.75
1948	6.05	2.60	4.57	4.21	8.73	3.91	3.20	2.80	1.25	4.89	7.86	3.29	53.36
1949	4.34	3.24	2.61	4.90	4.09	0.06	1.16	5.58	3.18	2.16	3.88	2.80	38.00
1950	3.65	4.78	4.10	4.21	3.58	2.79	1.10	4.75	1.87	2.31	7.48	4.87	45.49
Av. 22 yrs.	4.28	3.66	4.38	4.02	3.57	3.74	3.38	4.20	4.13	3.15	4.80	3.81	47.12

SCITUATE, R. I. (Gainer Dam—Formerly Kent)
Record: January, 1926, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.71	3.76	8.24	0.91	1.73	2.83	5.76	4.31	2.23	3.59	5.07	6.37	49.51
1943	3.45	1.79	3.53	3.75	3.34	1.87	2.27	2.27	1.30	6.80	2.52	1.16	34.05
1944	1.95	2.23	5.00	3.82	1.48	3.07	1.08	2.50	12.17	2.38	8.85	4.08	48.61
1945	3.15	5.25	2.29	2.88	3.83	5.53	2.08	2.97	3.54	2.07	8.72	7.94	50.25
1946	3.62	3.75	1.46	2.00	4.33	3.14	1.18	11.20	1.92	0.52	0.87	3.60	37.59
1947	3.14	1.53	4.47	5.74	3.13	3.95	3.77	3.84	2.89	3.41	7.28	3.09	46.24
1948	5.98	2.19	3.87	3.55	9.15	3.82	4.04	2.89	1.54	4.89	6.07	2.93	50.92
1949	4.52	3.64	1.91	5.10	3.35	0.06	1.71	4.42	3.46	1.90	3.10	2.54	35.71
1950	3.39	4.21	3.82	3.04	2.95	2.35	0.97	5.12	2.07	2.21	6.91	4.18	41.22
Av. 25 yrs.	4.05	3.57	4.08	4.04	3.29	3.41	3.10	4.35	4.02	3.29	4.71	3.79	45.70

SLOCUM, R. I.
Record: January, 1940, to September, 1948

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	3.65	3.01	4.25	5.51	5.01	2.33	3.56	1.80	2.16	2.11	6.97	2.68	43.04
1941	3.49	1.63	3.25	1.83	2.67	6.40	4.35	1.93	0.57	1.84	3.47	3.52	34.95
1942	4.66	4.75	6.57	1.47	1.81	2.34	4.88	6.67	2.23	4.76	6.04	6.70	52.88
1943	4.17	2.46	3.23	3.90	5.18	2.07	3.92	2.89	1.74	4.43	3.31	1.80	39.10
1944	2.49	2.18	5.61	3.95	1.20	3.02	0.40	2.05	6.33	2.46	10.27	3.67	43.63
1945	3.44	4.04	2.61	2.28	3.30	3.87	1.12	4.76	1.44	2.27	7.63	8.79	45.55
Av. 6 yrs.	3.64	3.01	4.25	3.16	3.19	3.35	3.04	3.34	2.41	2.98	6.28	4.53	43.19
1946	4.73	3.06	1.62	2.40	5.56	3.22	1.72	—	1.32	0.85	1.05	3.00	—
1947	3.77	0.70	3.26	5.20	4.56	3.92	5.20	2.45	2.48	4.90	5.90	3.27	45.61
1948	5.74	3.48	4.93	4.03	10.10	2.18	1.82	0.93	0.81	—	—	—	—

WESTERLY, R. I. (Weather Bureau—Formerly Everett Barnes)
Record: January, 1893, to October, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.45	3.26	6.53	0.86	2.28	1.83	4.37	5.42	1.76	3.42	4.57	5.82	44.57
1943	3.99	2.08	3.20	4.01	3.37	2.05	4.28	2.61	1.49	5.14	3.08	1.65	36.95
1944	3.73	2.32	5.93	4.26	1.15	3.38	0.68	1.60	7.51	2.37	10.89	3.90	47.72
1945	2.78	4.75	2.44	3.01	4.06	2.51	1.22	4.55	1.55	2.42	7.87	6.95	44.11
1946	4.85	3.11	1.71	2.29	5.94	3.09	2.19	11.81	2.11	1.06	0.95	3.14	42.25
1947	3.44	1.19	2.73	5.99	3.37	2.23	2.42	2.16	2.88	2.37	5.67	2.83	37.28
1948	6.49	2.97	4.86	3.71	8.90	2.30	2.35	0.80	0.99	3.23	5.69	2.52	44.81
1949	5.96	—	8.04	4.12	2.68	T	2.00	1.75	2.69	1.47	3.19	3.73	—
1950	3.46	4.23	3.75	2.56	4.82	2.94	1.85	4.75	1.36	1.75	—	—	—
Av. 56 yrs.	4.03	3.62	4.06	3.89	3.50	2.81	2.97	3.77	3.46	3.33	3.91	3.86	43.21

WESTERLY, R. I. (White Rock Pumping Station)
Record: January, 1912, to December, 1949

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1912	3.30	2.63	7.81	4.39	3.74	0.47	2.85	2.85	2.05	1.53	3.21	6.42	41.25
1913	4.24	3.38	3.74	7.38	2.10	1.00	1.33	2.17	3.61	5.50	1.96	4.48	40.89
1914	3.42	3.31	3.51	3.70	2.79	1.03	3.70	2.70	0.70	3.48	2.43	3.94	34.71
1915	8.91	5.60	0.17	1.61	3.16	1.67	1.30	7.18	1.82	3.65	1.81	3.96	40.84
1916	—	—	—	—	—	—	—	—	—	—	—	—	—
1917	2.63	2.63	5.82	1.85	2.95	3.77	2.64	6.01	3.55	5.69	0.32	2.32	40.18
1918	3.44	1.74	2.34	5.12	3.48	4.34	2.55	1.95	5.81	1.19	2.37	4.18	38.51
1919	3.73	4.01	5.36	3.95	3.57	2.08	4.31	5.51	8.56	1.97	3.84	3.98	50.87
1920	2.61	5.95	4.52	4.96	3.47	6.16	3.26	3.31	1.14	1.44	4.74	5.27	46.83
1921	2.56	2.59	3.32	4.19	5.33	2.55	3.37	2.39	1.06	1.66	9.69	2.52	41.23
1922	—	—	—	—	—	—	—	—	—	—	—	—	—
1923	5.88	1.55	5.34	5.73	1.54	2.76	2.40	2.21	3.56	3.95	4.45	6.18	45.55
1924	4.98	3.45	1.01	6.51	3.17	1.38	0.71	8.40	6.32	0.22	2.40	3.05	41.60
1925	3.23	2.10	2.69	2.66	4.18	2.96	3.52	2.35	3.01	5.53	5.03	3.46	40.72
1926	3.45	3.73	3.75	2.41	3.50	2.00	4.75	4.64	1.49	4.88	5.64	2.77	43.01

WESTERLY, R. I. (White Rock Pumping Station) (Continued)
Record: January, 1912, to December, 1949

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1927	2.74	2.48	2.52	2.51	3.58	4.00	4.67	10.54	4.00	5.19	11.34	5.82	59.39
1928	2.77	5.03	2.57	4.92	1.46	4.08	3.67	4.20	4.38	4.99	3.41	3.07	44.55
1929	4.19	4.14	5.09	6.68	4.08	0.50	2.51	3.40	5.00	2.28	3.27	5.57	46.71
1930	3.06	4.62	3.05	1.85	3.77	3.34	2.98	2.41	0.89	3.52	4.13	2.73	36.35
1931	5.00	2.08	6.45	3.36	4.02	5.67	4.28	6.30	0.55	3.28	1.04	5.79	47.82
1932	7.45	2.58	6.62	2.59	2.58	2.75	3.73	4.17	15.38	9.54	8.69	2.65	68.73
1933	2.86	4.39	6.69	5.97	4.36	2.95	3.28	5.81	7.75	3.37	3.29	2.86	53.58
1934	4.32	4.47	4.50	6.67	5.53	3.66	1.57	1.58	5.51	3.51	5.30	3.94	50.56
1935	6.41	3.68	3.01	4.09	1.92	6.25	6.52	1.14	4.37	1.49	6.11	0.56	45.55
1936	7.88	4.83	10.75	3.71	2.95	6.94	1.37	4.96	5.54	4.23	1.00	11.90	66.06
1937	6.06	2.36	4.98	5.79	3.23	4.28	2.21	3.85	3.10	3.82	7.24	3.33	50.25
1938	3.83	3.17	3.11	3.87	4.54	6.81	6.11	4.07	6.55	3.53	3.13	3.95	52.67
1939	4.01	6.68	6.35	6.57	1.81	2.21	1.40	7.78	2.32	5.59	1.62	2.49	48.83
1940	3.23	5.32	4.74	7.07	4.74	1.73	3.72	0.74	2.85	1.69	6.16	2.50	44.49
1941	2.31	1.72	2.27	1.57	2.37	4.34	5.42	2.92	2.03	0.43	4.13	2.80	32.31
1942	4.40	3.20	6.65	0.78	1.72	1.13	4.67	5.37	1.09	2.97	4.07	6.45	42.50
1943	3.19	1.79	3.03	3.16	3.53	1.37	3.59	2.56	1.37	5.41	2.58	1.50	33.08
1944	3.40	1.90	5.54	4.27	1.02	3.30	0.63	1.53	7.29	2.08	11.04	3.69	45.69
1945	2.19	4.34	2.44	2.82	3.76	2.01	1.30	4.08	1.43	2.38	7.82	6.80	41.37
1946	4.58	3.06	1.58	2.32	5.23	2.86	2.42	11.77	2.03	1.02	0.79	3.03	40.69
1947	3.44	1.19	2.73	5.99	3.37	2.23	2.42	2.16	2.88	2.37	5.67	2.83	37.28
1948	6.49	2.97	4.86	3.71	8.90	2.30	2.35	0.80	0.99	3.23	5.69	2.52	44.81
1949	5.96	4.23	3.81	4.12	2.68	—	2.00	1.75	2.69	1.47	3.01	3.73	—
1950	—	—	—	—	—	—	—	—	—	—	—	—	—
Av. 35 yrs.	4.18	3.39	4.25	4.13	3.47	3.05	3.07	4.11	3.71	3.33	4.44	3.98	45.11

WOOD RIVER JUNCTION, R. I.
Record: January, 1940, to September, 1948

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	3.66	3.33	4.62	6.07	4.46	2.55	4.01	3.45	3.73	2.34	7.11	2.97	48.30
1941	3.55	1.86	3.64	1.47	2.36	5.18	5.16	2.77	0.35	2.43	3.98	3.04	35.79
1942	3.37	4.95	6.96	0.84	2.00	1.80	5.03	6.65	1.93	4.08	5.55	6.37	49.53
1943	4.03	2.58	3.49	3.83	3.63	2.02	2.95	2.78	1.08	5.48	3.04	1.59	36.50
1944	3.41	2.52	6.19	4.04	1.57	3.21	1.07	0.98	7.89	2.29	8.28	2.77	44.22
1945	3.92	4.76	2.83	3.11	4.38	3.67	1.54	4.08	1.10	2.68	8.61	7.00	47.68
Av. 6 yrs.	3.66	3.33	4.62	3.23	3.07	3.07	3.29	3.45	2.68	3.22	6.09	3.96	43.67
1946	5.02	3.32	1.97	2.47	5.12	3.30	2.60	13.82	2.50	1.20	0.87	2.95	45.14
1947	4.03	1.38	4.05	5.00	4.45	3.44	2.65	2.32	2.17	3.24	6.44	3.30	42.47
1948	6.52	2.97	5.44	3.92	10.44	2.23	1.91	1.15	1.41	—	—	—	—

WOONSOCKET, R. I. (Weather Bureau)
Record: April, 1941, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	—	—	—	1.25	2.22	3.44	6.26	2.07	1.41	1.10	2.77	3.17	—
1942	3.92	2.44	6.87	0.78	2.51	—	—	—	—	3.11	4.82	5.92	—
1943	—	—	3.17	3.63	3.98	2.37	4.92	1.59	0.78	4.03	2.78	1.09	—
1944	1.40	2.03	4.14	4.02	1.28	3.80	0.93	0.62	7.67	2.34	6.01	2.69	36.93
1945	2.80	4.51	1.81	2.63	3.75	6.00	3.12	3.34	1.35	1.62	6.81	5.20	42.94
1946	2.62	2.08	1.29	1.82	3.77	3.13	1.27	8.93	2.37	0.28	0.81	3.73	32.10
1947	2.90	1.56	2.79	3.58	3.82	3.81	4.35	1.98	4.09	1.29	6.54	3.32	40.03
1948	3.55	1.20	3.33	2.78	7.42	6.15	2.30	1.59	3.52	5.68	1.97	—	—
1949	2.80	2.60	2.07	3.66	2.83	0.20	0.82	3.91	4.68	1.62	2.92	1.60	29.71
1950	3.20	4.04	3.46	2.92	1.86	2.02	1.85	4.20	1.06	2.40	5.94	3.59	36.54
Av. 6 yrs.	2.62	2.80	2.59	3.10	2.88	3.16	2.06	3.83	3.54	1.59	4.84	3.35	36.36

PROCEEDINGS

APRIL 1956 MEETING

PICKWICK ARMS HOTEL, GREENWICH, CONN.

THURSDAY, APRIL 19, 1956

More than 160 members of the Association and their guests took advantage of the opportunity to visit and inspect the Putnam and Mianus Filter Plants and the Mianus Reservoir of the Greenwich Water Co.

The group returned to the Pickwick Arms Hotel, where luncheon was served. President Allan F. McAlary introduced those at the head table and called upon Walter A. Hayes, First Selectman, who extended a most cordial welcome on behalf of the town of Greenwich.

Introductory remarks concerning the development of the Greenwich Water Co. were given by Manager Robert A. Kaufman.

A paper, "Construction of the Mianus Dam and Reservoir", was read by George E. Paul, Chief Construction Engineer, American Water Works Service Co., Philadelphia, Pa.

An illustrated paper, "The Design of the Mianus Filter Plant", was read by Howard J. Carlock, Chief Design Engineer, American Water Works Service Co., Philadelphia, Pa.

MAY 1956 MEETING

ROGER SMITH HOTEL, HOLYOKE, MASS.

THURSDAY, MAY 17, 1956

About 218 members and guests of the Association participated in an escorted motorcade to the site of the New Manhan Dam, currently under construction. This huge project was extremely interesting, and perfect weather made a complete inspection possible.

Luncheon was served at the Roger Smith Hotel, after which President Allan F. McAlary introduced those at the head table.

A warm welcome was afforded the group by James E. Barry, Chairman of the Board of Water Commissioners of the city of Holyoke.

An illustrated paper, "The Need for the Holyoke Expansion", was presented by George H. Shea, Engineer, Water Works, Holyoke, Mass.

An illustrated paper, "Interesting Construction Features of the New Dam", was presented by George H. McDonnell, Consulting Engineer, Tighe & Bond, Inc., Holyoke, Mass.

INDEX OF ADVERTISERS

	Page
Badger Meter Mfg. Co.	Following front cover
Bahr, Ray	xviii
B-I-F Industries, Inc.	iv
Bingham & Taylor Corp.	Following front cover
Brown Co.	xviii
Caldwell Co., George A.	iv
Camp, Dresser & McKee	ii
Cast Iron Pipe Research Assn.	xxv
Cement Lined Pipe Co.	xviii
Centriline Corp.	Following front cover
Chapman Co., R. E.	ii
Coffin and Richardson	ii
Crosby, Irving B.	ii
Dresser Mfg. Div.	xx
Eddy Valve Co.	xii
Eureka Pipe Co., Inc.	xiv
Fairbanks, Morse & Co.	Following front cover
Fay, Spofford & Thorndike	ii
Flexible, Inc.	xviii
Ford Meter Box Co., The	Following front cover
Gunite Restoration Co., Inc.	ii
Haley & Ward	ii
Hays Mfg. Co.	xiii
Hazen & Sawyer	iii
Hersey Mfg. Co.	ix
Hilco Supply, Inc.	xix
Hydraulic Development Corp.	vii
Johns Manville Sales Corp.	viii
Keasbey & Mattison Co.	v
Kennedy Valve Mfg. Co.	xv
Knowles, Inc., Morris	ii
Layne-New York Co.	iii
Leadite Co.	Back cover
Leggette, Brashears & Graham	ii
Lock Joint Pipe Co.	Following front cover
Ludlow Valve Mfg. Co.	Following front cover
Maguire & Assoc., Chas. A.	iii
Maher Co., D. L.	iii
Metcalf & Eddy	ii
Mills Engineering Co., Inc.	xiv
Morris Knowles, Inc.	ii
Mueller Co.	Following front cover
National Water Main Cleaning Co.	x
Neptune Meter Co.	Following front cover
Pierce-Perry Co.	iii
Pipe Founders Sales Corp.	xiv
Pirnie, Malcolm	iii
Pitometer Assoc., Inc., The	iii
Pittsburgh-Des Moines Steel Co.	Following front cover
Pittsburgh Equitable Meter Div.	Following front cover
Pollard Co., Inc., Joseph G.	Following front cover
Prescott & Sons, Inc., H. R.	xvi
Public Works Supply Co.	xviii
Rensselaer Valve Co.	Following front cover
Rockwell Manufacturing Co.	Following front cover
Ross Valve Mfg. Co.	xvii
Smith and Norrington Engineering Corp.	iii
Smith Mfg. Co., The A. P.	Following front cover
Torrington Supply Co., Inc.	xvi
Turbine Equipment Co. of New England	Following front cover
U. S. Cast Iron Pipe & Foundry Co.	xxvi
Utilities Supply Corp.	xix
Wallace & Tiernan Co., Inc.	xi
Warren Foundry & Pipe Div., Shamoon Industries, Inc.	Following front cover
Weston & Sampson	iii
White Construction Co., R. H.	xiv
Whitman & Howard	iii
Wood Co., R. D.	Following front cover
Worthington-Gamon Meter Div.	vi

(Classified index on page xxiii)

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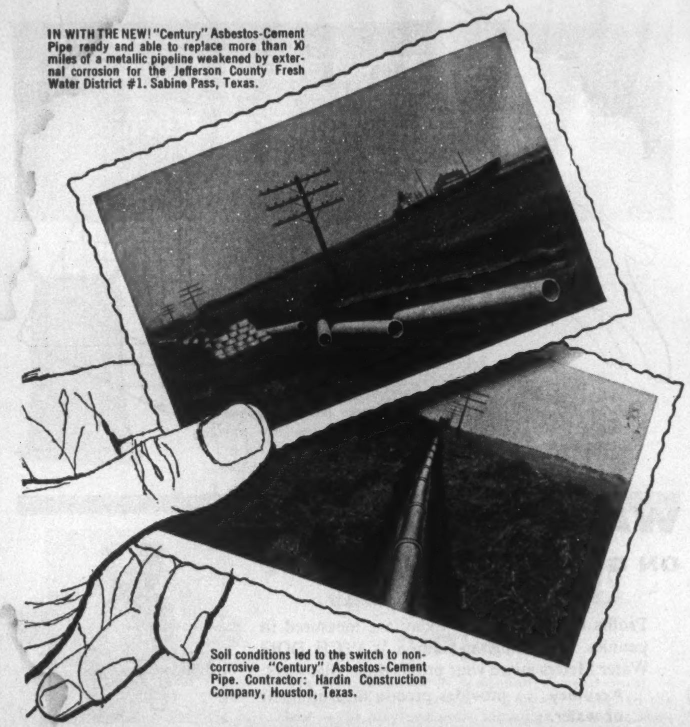

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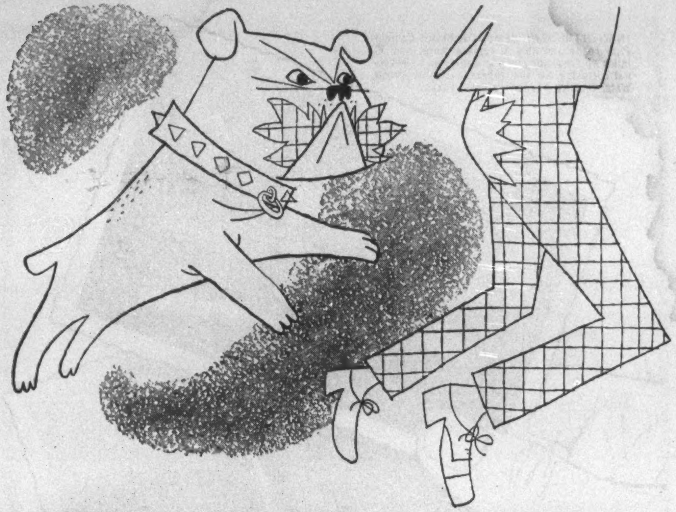

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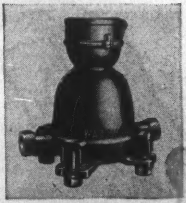

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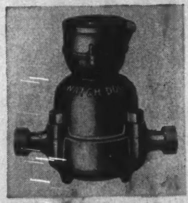

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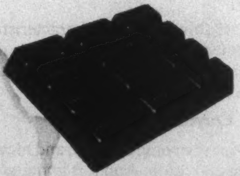

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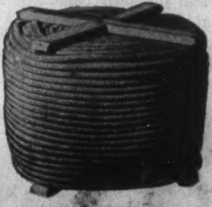

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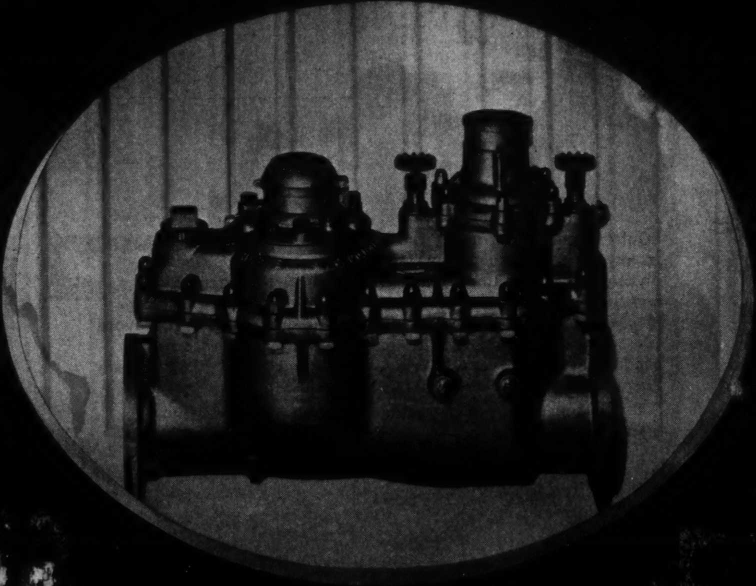

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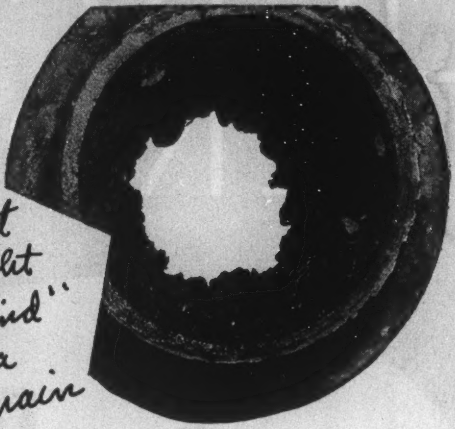

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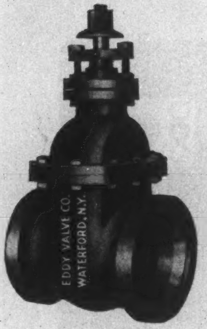

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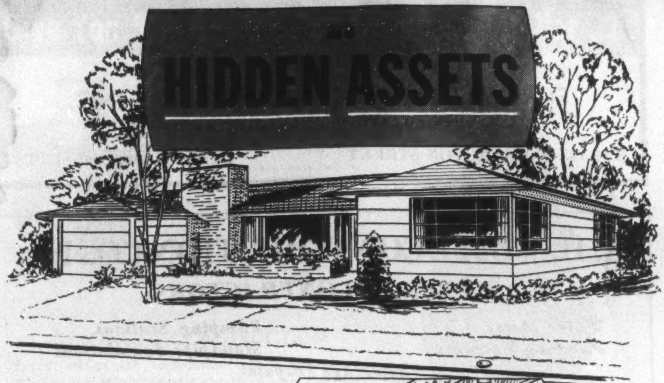

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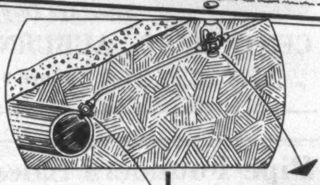

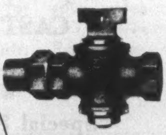

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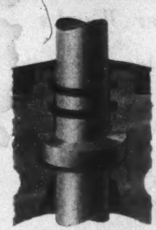

O-RING SEALS

Provide excellent seal, prevent binding of stem and result in very easy valve operation. KENNEDY O-Rings are located above collar, permit repacking under pressure. Optional on KENNEDY non-rising stem A.W.W.A. valves.

KENNEDY Fig. 56
A.W.W.A. Standard Iron-Body Double-Disc Gate Valve, with Bell Ends.

STRONGER CONSTRUCTION

Rugged design and construction features iron that is 50% stronger than ordinary cast iron to keep KENNEDY Valves doing a better job over a longer, more dependable operating life.

KENNEDY manufactures a complete line of water works valves. Sizes range from 2″ to 48″ including non-rising stem and outside-screw-and-yoke valves. These valves feature the hook-and-wedge type disc mechanism for easier, better and more positive valve operation. A wide variety of pipe connections are available.

For maximum service life, for the greatest value for your valve dollar, specify KENNEDY valves and fire hydrants. Remember, KENNEDY means dependability in valves, fire hydrants and accessories.

Fig. 571

Fig. 561

Fig. 566

Fig. 566G

Fig. 566FTR

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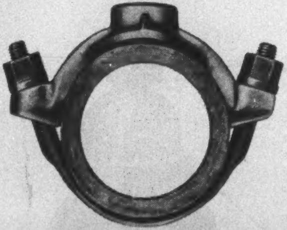

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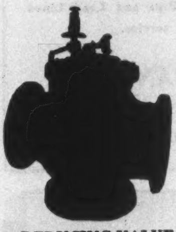
Controls elevation
of water
in
tanks, basins
and
reservoirs

ALTITUDE VALVE

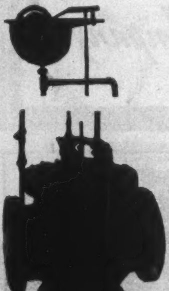
1. Single Acting
2. Double Acting



Maintains
desired discharge
pressure
regardless
of change
in
rate of flow

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



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levels in tank,
reservoir
or basin

1. As direct acting

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

FLOAT VALVE

A self contained
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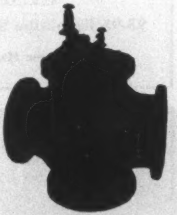
controls
three or more
automatic

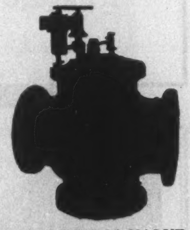
COMBINATION VALVE

Combination automatic control both directions through the valve.



Maintains
safe operating
pressures
for
conduits,
distribution and
pump
discharge

SURGE-RELIEF VALVE



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motor
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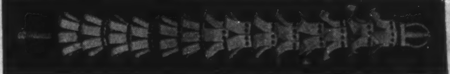

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CLASSIFIED DIRECTORY OF ADVERTISEMENTS

ASBESTOS-CEMENT PIPE.	
Johns-Manville	viii
Keasbey & Mattison Company	v
BRASS GOODS.	
Caldwell Co., George A.	iv
Eureka Cement Lined Pipe Co.	xiv
Hilco Supply	xix
Mueller Co.	Following front cover
Pierce-Perry Co.	iii
Torrington Supply Co., Inc.	xvi
Utilities Supply Corp.	xix
CALKING MACHINERY AND TOOLS.	
Hydraulic Development Corp.	vii
Mueller Co.	Following front cover
CAST IRON PIPE. (See Pipe, Cast Iron.)	
CEMENT LINED PIPE. (See Pipe, Cement Lined.)	
CHEMICAL FEED APPARATUS.	
B-I-F Industries	iv
Wallace & Tiernan Co., Inc.	xi
CHLORINATORS.	
B-I-F Industries	iv
Wallace & Tiernan Co., Inc.	xi
CLARIFIERS.	
Mills Engineering Co., Inc.	xiv
CLEANING WATER MAINS.	
Flexible Pipe Cleaning Co.	xviii
National Water Main Cleaning Co.	x
COCKS, CURBS AND CORPORATIONS.	
Caldwell Co., George A.	iv
Eureka Cement Lined Pipe Co.	xiv
Hays Mfg. Co.	xiii
Mueller Co.	Following front cover
Pierce-Perry Co.	iii
Utilities Supply Corp.	xix
CONCRETE PIPE. (See Pipe, Concrete.)	
CONTRACTORS' EQUIPMENT.	
Hydraulic Development Corp.	vii
CONTRACTORS.	
Layne-New York Co., Inc.	iii
Maher, D. L. Co.	iii
White Construction Co., R. H.	xiv
COUPLINGS, FLEXIBLE PIPE.	
Caldwell Co., George A.	iv
Dresser Mfg. Div.	xx
Public Works Supply Company	xviii
CURB BOXES.	
Bingham & Taylor Corp.	Following front cover
Caldwell Co., George A.	iv
Eureka Cement Lined Pipe Co.	xiv
Hays Mfg. Co.	xiii
Hilco Supply	xix
Mueller Co.	Following front cover
Pierce-Perry Co.	iii
H. R. Prescott & Sons, Inc.	xvi
Public Works Supply Company	xviii
Utilities Supply Corp.	xix
DIAPHRAGMS, PUMPS.	
Joseph G. Pollard Co.	Following front cover
EJECTOR, PNEUMATIC.	
Mills Engineering Co., Inc.	xiv
ENGINEERS.	
Camp, Dresser & McKee	ii
Coffin & Richardson	ii
Crosby, Irving B.	ii
Fay, Spofford and Thorndike	ii
Haley and Ward	ii
Hazen and Sawyer	iii
Knowles Morris, Inc.	ii
Leggette, Brashears & Graham	ii
Maguire & Associates, Charles A.	iii
Metcalf and Eddy	ii
Pirnie Engineers, Malcolm	iii
Pitometer Associates, Inc., The	iii
Smith and Norrington	iii
Weston and Sampson	iii
Whitman and Howard	iii
ENGINES. (See Pumps and Pumping Engines.)	
EQUIPMENT. (See Contractors' Equipment.)	

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

FEED WATER FILTERS.	
Ross Valve Mfg. Co., Inc.	xvii
FILTRATION PLANT EQUIPMENT.	
B-I-F Industries	iv
Mills Engineering Co., Inc.	xiv
FLAP VALVES.	
Eddy Valve Co.	xii
FLEXIBLE JOINTS.	
Dresser Mfg. Div.	xx
U. S. Pipe and Foundry Co.	xxvi
FURNACES.	
Hilco Supply	xix
Hydraulic Development Corp.	vii
Leadite Co., The	Back cover
Mueller Co.	Following front cover
Pollard Co., Joseph G.	Following front cover
H. R. Prescott & Sons, Inc.	xvi
Public Works Supply Company	xviii
Utilities Supply Corp.	xix
GATE VALVES. (See Valves.)	
GEARS.	
Mills Engineering Co., Inc.	xiv
GUNITE CONSTRUCTION.	
Gunite-Restoration Co., Inc.	ii
HOSE, SUCTION AND CONDUCTION.	
H. R. Prescott & Sons, Inc.	xvi
HYDRANTS, FIRE.	
Caldwell Co., George A.	iv
Eddy Valve Co.	xii
Hilco Supply	xix
Kennedy Valve Mfg. Co.	xv
Ludlow Valve Mfg. Co.	Following front cover
Mueller Co.	Following front cover
H. R. Prescott & Sons, Inc.	xvi
Public Works Supply Company	xviii
Rensselaer Valve Co.	Following front cover
Smith Mfg. Co., The A. P.	Following front cover
Utilities Supply Corp.	xix
Wood, R. D., Co.	Following front cover
HYDRANTS, PUMPS.	
Hilco Supply	xix
Joseph G. Pollard Co.	Following front cover
H. R. Prescott & Sons, Inc.	xvi
LEAD PIPE. (See Pipe, Lead.)	
LIQUID CHLORINE.	
Brown Co.	xviii
METERS, OIL AND WATER.	
Badger Meter Mfg. Co.	Following front cover
B-I-F Industries	iv
Hersey Mfg. Co.	ix
Neptune Meter Co.	Following front cover
Pipe Founders Sales Corp.	xiv
Pittsburgh Equitable Meter Div.	Following front cover
Worthington-Gamon Meter Div.	vi
METER COUPLINGS.	
Badger Meter Mfg. Co.	Following front cover
Caldwell Co., George A.	iv
Ford Meter Box Co.	Following front cover
Hays Mfg. Co.	xiii
Hersey Mfg. Co.	ix
Mueller Co.	Following front cover
Neptune Meter Co.	Following front cover
Public Works Supply Company	xviii
Worthington-Gamon Meter Div.	vi
METERS (Venturi Type.)	
B-I-F Industries	iv
METER BOXES.	
Bingham & Taylor Corp.	Following front cover
Ford Meter Box Co.	Following front cover
Mueller Co.	Following front cover
Public Works Supply Company	xviii
METER TESTERS.	
Badger Meter Mfg. Co.	Following front cover
Ford Meter Box Co.	Following front cover
Mueller Co.	Following front cover
Neptune Meter Co.	Following front cover
Public Works Supply Company	xviii
OIL ENGINES.	
Fairbanks, Morse & Co.	Following front cover
PIPE, ASBESTOS-CEMENT.	
Johns-Manville	viii
Keasbey & Mattison Company	v

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

SLEEVES AND VALVE TAPPINGS.

Caldwell Co., George A.	iv
Eddy Valve Co.	xii
Hilco Supply	xix
Ludlow Valve Mfg. Co.	Following front cover
Mueller Co.	Following front cover
H. R. Prescott & Sons, Inc.	xvi
Public Works Supply Company	xviii
Rensselaer Valve Co.	Following front cover
Smith Mfg. Co., The A. P.	Following front cover
Utilities Supply Corp.	xix

STEEL PLATE WORK.

Pittsburgh-Des Moines Steel Co.	Following front cover

STRAINERS.

Mills Engineering Co., Inc.	xiv

SUPPLIES AND TOOLS.

Caldwell Co., George A.	iv
Hilco Supply	xix
Hydraulic Development Corp.	vii
Leadite Co., The	Back cover
Mueller Co.	Following front cover
Pierce-Perry Co.	iii
Pollard Co., Joseph G.	Following front cover
H. R. Prescott & Sons, Inc.	xvi
Public Works Supply Company	xviii

TAPPING MACHINES.

Caldwell Co., George A.	iv
Hays Mfg. Co.	xiii
Mueller Co.	Following front cover
Smith Mfg. Co., The A. P.	Following front cover

TANKS, STEEL.

Pittsburgh-Des Moines Steel Co.	Following front cover

TAPPING SLEEVES. (See Sleeves and Valves, Tappings.)

VALVE BOXES.

Bingham & Taylor Corp.	Following front cover
Caldwell Co., George A.	iv
Eddy Valve Co.	xii
Hilco Supply	xix
Kennedy Valve Mfg. Co.	xv
Mueller Co.	Following front cover
Pierce-Perry Co.	iii
Pipe Founders Sales Corp.	xiv
H. R. Prescott & Sons, Inc.	xvi
Public Works Supply Company	xviii
Smith Mfg. Co., The A. P.	Following front cover
Utilities Supply Corp.	xix
Wood, R. D., Co.	Following front cover

VALVE AND GATE GENERATORS.

Mills Engineering Co., Inc.	xiv

VALVE INSERTING MACHINES.

Mueller Co.	Following front cover
Smith Mfg. Co., The A. P.	Following front cover

VALVES, CHLORINE.

Wallace & Tiernan Co., Inc.	xi

VALVES, GATE.

Caldwell Co., George A.	iv
Eddy Valve Co.	xii
Hilco Supply	xix
Kennedy Valve Mfg. Co.	xv
Ludlow Valve Mfg. Co.	Following front cover
Mueller Co.	Following front cover
Pierce-Perry Co.	iii
H. R. Prescott & Sons, Inc.	xvi
Public Works Supply Company	xviii
Rensselaer Valve Co.	Following front cover
Smith Mfg. Co., The A. P.	Following front cover
Torrington Supply Co., Inc.	xvi
Utilities Supply Corp.	xix
Wood, R. D., Co.	Following front cover

VALVES, REGULATING.

Mueller Co.	Following front cover
Ross Valve Mfg. Co., Inc.	xvii

WASH FOUNTAINS.

Mills Engineering Co., Inc.	xiv

WATER-PROOFING.

Gunite Restoration Co., Inc.	ii

WATER WASTE DETECTION.

Pitometer Associates, Inc., The	iii

WELLS, GRAVEL, FILTER AND DRIVEN.

Layne-New York Co., Inc.	iii
Maher Co., D. L.	iii

WROUGHT IRON PIPE. (See Pipe, Wrought Iron and Steel.)

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

PIPE, BRASS.
Caldwell Co., George A. iv
Hilco Supply xix
Pierce-Perry Co. iii
H. R. Prescott & Sons, Inc. xvi
Torrington Supply Co., Inc. xvi
Utilities Supply Corp. xix

PIPE, CAST IRON (and Fittings.)
B-I-F Industries iv
Bingham & Taylor Corp. .... Following front cover
Cast Iron Pipe Research Association xxv
Hilco Supply xix
Pipe Founders Sales Corp. xiv
H. R. Prescott & Sons, Inc. xvi
U. S. Pipe and Foundry Co. xxvi
Utilities Supply Corp. xix
Wood, R. D., Co. .... Following front cover

PIPE, CEMENT LINED.
Cast Iron Pipe Research Association xxv
Cement Lined Pipe Co. xviii
Eureka Cement Lined Pipe Co. xiv
Pipe Founders Sales Corp. xiv
U. S. Pipe and Foundry Co. xxvi
Utilities Supply Corp. xix

PIPE, COATING AND LININGS.
Centriline Corp. .... Following front cover

PIPE, CONCRETE.
Lock Joint Pipe Co. .... Facing front cover

PIPE CUTTING MACHINES.
Caldwell Co., George A. iv
Pollard Co., Joseph G. .... Following front cover
Smith Mfg. Co., The A. P. .... Following front cover

PIPE JOINTING MATERIAL.
Caldwell Co., George A. iv
Hilco Supply xix
Hydraulic Development Corp. vii
Leadite Co., The .... Back cover
Utilities Supply Corp. xix

PIPE, LEAD.
Pierce-Perry Co. iii

PIPE LINING.
Cement Lined Pipe Co. xviii
Centriline Corp. .... Following front cover

PIPE, PRESTRESSED CONCRETE.
Lock Joint Pipe Co. .... Facing front cover

PIPE, WROUGHT IRON AND STEEL.
Pierce-Perry Co. iii
Torrington Supply Co., Inc. xvi

PLUG VALVES.
Eddy Valve Co. xii
Hays Mfg. Co. xiii
Mueller Co. .... Following front cover
Pittsburgh Equitable Meter Div. .... Following front cover

PITOMETERS.
Pitometer Associates, Inc., The iii

PORTABLE AIR COMPRESSORS. (See Air Compressors.)

PRESSURE REGULATORS.
Hilco Supply xix
Mueller Co. .... Following front cover
Pittsburgh Equitable Meter Div. .... Following front cover
H. R. Prescott & Sons, Inc. xvi
Ross Valve Mfg. Co., Inc. xvii

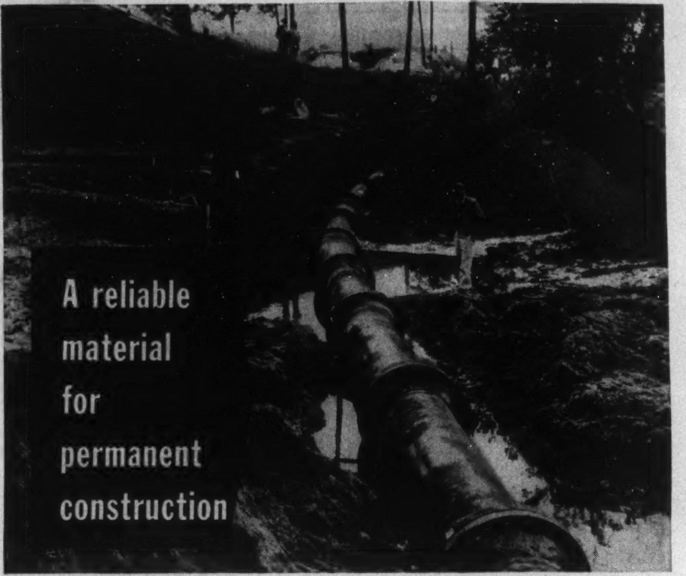
PROVERS, WATER.
Badger Meter Mfg. Co. .... Following front cover
Ford Meter Box Co. .... Following front cover

PUMPS AND PUMPING MACHINES.
Fairbanks, Morse & Co. .... Following front cover
Layne-New York Co., Inc. iii
Hilco Supply xix
Maher Co., D. L. iii
Mills Engineering Co., Inc. xiv
Joseph G. Pollard Co. .... Following front cover
H. R. Prescott & Sons, Inc. xvi
Ross Valve Mfg. Co., Inc. xvii
Turbine Equipment Co. .... Following front cover
White Construction Co., R. H. xiv

RATE CONTROLLERS AND GAUGES.
Badger Meter Mfg. Co. .... Following front cover
B-I-F Industries iv

REDUCERS, SPEED.
Mills Engineering Co., Inc. xiv

SHEAR GATES.
Eddy Valve Co. xii
Mueller Co. .... Following front cover



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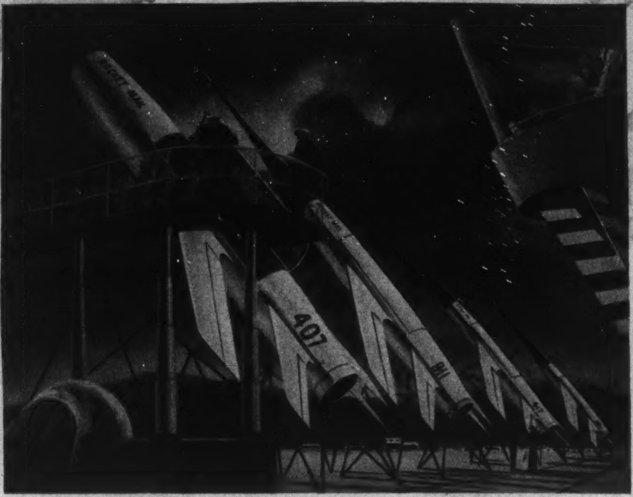

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Tested and used for over 40 years,
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